Physics Literature

A Reference Manual

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To my Mother

PREFACE

This is a survey of physics literature at the college level. It describes the many types and forms available, selects a representative working collection, and outlines efficient library methods. Arrangement is by most usual lines of inquiry, termed "approaches," e.g., the historical approach when items pertaining to history are sought. Background materials have been interspersed for greater interest and information.

In his efforts to produce a helpful guide, the writer has drawn upon long experience in an active science-technology library, with an interlude of college physics teaching.

Warm thanks for help on many occasions go to Professors Carter Alexander, S. Ralph Powers, Robert Bruce Raup, and Eleanor M. Witmer of Teachers College, Columbia University, and to fellow librarians at the New York Public Library, the Engineering Societies Library, and the various libraries on the campuses of Columbia University and the City College of New York.

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CHAPTER I

INTRODUCTION

Physics is the subject of concentration of this guide; material from related fields is cited only when necessary for background purposes. Most books listed are at the college level; lucid comprehensive presentations readily absorbed by college students usually take precedence over advanced mathematical monographs intelligible only to specialists. Of course, a specialist seeking data outside his own familiar field will find these helpful.

Scope.

A guide to special subject literature should give representative sources and indicate how to proceed further, for indiscriminate listing of all possible references would be a disservice to users seeking orientation and guidance. Accordingly, this guide comprises material selected according to the following criteria:

(1) Is it a useful bibliographical tool? (For example, a periodical indexing medium.)
(2) Is it a comprehensive reference work? (These are designed to yield needed data rather than for reading through.)
(3) Does it sketch a particular aspect well? (For example —biographical.)
(4) Does it fill a major subject gap? (E.g., ultrasonics.)
(5) Is it a recent publication? (These usually supersede and review previous work.)
(6) Might it be termed a "classic?" (A time-honored book possessing lasting utility, as well as historical interest.)
(7) Has it reached the multi-edition stage? (Thereby denoting widespread acceptance through merit.)
(8) Is the author an authority in his field? (E.g., Loeb for electric gas discharge; Aston for mass spectra.)

(9) Is it otherwise a noteworthy publication?

Besides indicating informational sources and outlining special techniques, this guide sketches physics literature in general, so as to call attention to the different kinds of printed materials available but often overlooked.

Omission of a particular book does not imply lack of merit, as this is not a roster of "best books." Instead, the books cited are those most useful for present purposes, viz., to furnish helpful guidance and a basic collection of sources. Sometimes equally good titles have been omitted for quantitative reasons, as in the field of mechanics which is so profusely covered by textbooks differing in arrangement, style, and scope. No compiler being infallible, some important books have possibly been overlooked. However, these inadvertent omissions have been minimized by employing parallel methods of compilation. Four extensive technical library collections[1] were surveyed through their card catalogs and by examination of the stacks as well. These searches were supplemented by gleanings from publishers' catalogs, book reviews, bibliographies, etc. Moreover, the writer's many years of active service in a technical library furnished first-hand subjective knowledge of most useful references.

As Jones states, "Any guide must be selective, partial, and fairly quickly obsolescent."[2] Hence the user cannot hope to find every worthwhile book listed among the pages of this guide, especially if publication dates prevent inclusion.

Arrangement.

The entire guide is arranged according to a multi-approach pattern, based on the various aspects of physics that an information seeker may have in mind. For example, he may wish biographical, experimental, or terminological material, or he may be concerned with educational implications. Such phases are termed approaches, because they represent usual lines of in-

1. New York Public Library, Columbia University, Engineering Societies, and City College of New York.
2. E. L. Jones, "Searching the Literature of Science." *Journal of Scientific Instruments*, 17:253-257, November 1940.

quiry (as indicated in the Preface). In addition, there is the topical approach, pursued whenever items on a physics subject *per se* are sought.

In each chapter explanatory text and book citations have been organized into a connected account so as to lead the reader from one group of references to the next, preserving continuity and facilitating comparison. Relevant background material has been interspersed throughout to increase general interest and usefulness. Descriptive notes are given for individual books whenever special features, not indicated by their grouping or titles, merit attention. Overviews and summaries round out and coordinate the whole.

Research aspects.

Whitney has accorded recognition to library and documentary research as follows:

> Descriptive research may be in terms of surveys and critical analyses of available data in printed form. This is informational analysis, or library research as it is called at times. It constitutes one technique of historical research, as history deals with records of the past. Obviously, making bibliographical lists is not research; but a critical evaluation of a unitary group of material with interpretation in terms of comparison and generalization may employ reflective thinking.[3]

This guide represents a borderline contribution between the fields of physics and library science. Spratt boasts of this interlinkage of subject specialization and librarianship in following vein:

> As a scientific librarian, it would be shameful of me to claim that our qualifications were above those for other branches of librarianship; but it must be admitted that with Scientific literature, as opposed to what the Germans would call "Schöne Literatur," the subject-matter aspect is more important than the author. Now the compilation of an alphabetical author-index is more or less routine work, but the precise subject-matter classification of Scientific literature requires one to be specialist as well as librarian; in short, a *super*-librarian.[4]

In its efforts to provide a unified view of physics literature in broad perspective, this book is in harmony with one of the prin-

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3. F. L. Whitney, *The Elements of Research*, p. 178. (Third Edition.) New York: Prentice-Hall, Inc., 1950.
4. H. P. Spratt, *Libraries for Scientific Research . . .*, p. 10-11. London: Grafton and Company, 1936.

cipal tenets of modern education,—integration[5]. This implies unity achieved by fusing all elements after establishing interrelationships among them.

Finally, the chapter on the Educational Approach is of particular significance to educators engaged in science teaching.

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5. See I. G. Barbour, "Integration as an Objective in the Physical Sciences." *American Journal of Physics*, 20: 565-568, December 1952.

CHAPTER II

BIBLIOGRAPHICAL APPROACH
Serials, Books, and Library Usage

The "bibliographical approach" is here taken to signify a broad, general approach to physics literature in periodical or book form, rather than preoccupation with bibliographical *lists per se.* This alternative is sanctioned by one Funk and Wagnalls definition of bibliography as works collectively bearing on a particular subject, whether listed or not.

1—Serial Publications

Periodicals are publications that appear in a continuing series of issues, usually at regular intervals, under the same distinctive title. Serials are likely to have discrete characteristics with respect to content, title and publication date. Whenever units of a serial or pseudo-serial set are shelved together in sequence within a library, they may be requested and located most conveniently from the series note on the catalog card (in parentheses after pagination, sometimes conspicuously underlined in red). For example, see the entry for H. C. Bolton's *Catalogue* referring to *Smithsonian Miscellaneous Collections Vol. 40.* (Excepted are the scattered books of commercial series such as *Methuen's Monographs.*)

General.

One turns to periodicals for the latest work in a given field, and for material on topics too small to warrant book treatment. In general, books are behind current practice because of compilation and publication delays. As Spratt declares:

> To collect the material for a comprehensive text-book, to hammer it into a presentable manuscript, is tedious work for the conscientious author, and cannot be hurried. It follows that when his book has at

last been printed and published, it is already out-of-date for the scientific research worker who wants to know what was done last week in his particular field. For such readers, continual reference must be made to the most recent articles in current periodicals.[1]

An interesting descriptive and historical account of physics periodical literature has been contributed by Roller[2]. For a statistical study of journal citations, subject interrelationships, and implications for librarians, see Fussler[3].

Selective lists of current periodicals, arranged in classified grouping with subject-title indexes, are found in the following convenient guides:

a. *Ulrich's Periodicals Directory,* edited by Eileen C. Graves. (Seventh Edition.) New York: R. R. Bowker Company, 1953. 684 pp.

b. Lyle, Guy R., and Trumper, V. M. *Classified List of Periodicals for the College Library.* (Third Edition.) Boston: F. W. Faxon Company, 1948. 99 pp.

See also A.C.R.L. Monograph No. 9 (1953): *A Recommended List of Basic Periodicals in Engineering and the Engineering Sciences,* prepared by a Special Committee of the Pure and Applied Science Section, Association of College and Reference Libraries, under the chairmanship of William H. Hyde.

To ascertain which library possesses files of particular journals, as well as for checking publication details, one consults union lists. The most comprehensive of these is the following general compilation:

Union List of Serials in Libraries of the United States and Canada, edited by Winifred Gregory. (Second Edition.) New York: The H. W. Wilson Company, 1943. 3065 pp.

—*First Supplement:* 1941-1943. (Published 1945.) 1123 pp. For each periodical, holdings are indicated alongside the name of the library in symbol form. For example, NNE means

1. H. P. Spratt, *op. cit.*, p. 10.
2. D. Roller, "The Periodical Literature of Physics." *American Journal of Physics,* 14: 300-308, September-October 1946.
3. H. H. Fussler, "Characteristics of the Research Literature Used by Chemists and Physicists in the United States." *Library Quarterly,* 19: 19-35, 119-143, January-April 1949.

the Engineering Societies Library, New York, as the end-paper chart shows. Besides indicating location of sets, entries yield other useful information about periodical publication spans,[4] mergers, changes of title, volume numbers, etc. Appended (pp. 3053-3065) is an extensive bibliography of similar union lists.

—*Second Supplement:* "Checking Edition" in progress.

Holdings of smaller technical libraries are surveyed by:

Special Libraries Association. *Union List of Technical Periodicals in Two Hundred Libraries of the Science-Technology Group of the Special Libraries Association,* compiled by E. G. Bowerman. (Third Edition.) New York: The Association, 1947. 285 pp.

A comprehensive British union list is:

World List of Scientific Periodicals Published in the Years 1900-1950, compiled by W. A. Smith, *et al.* (Third Edition.) London: Butterworths Scientific Publications,[5] 1952. 1058 pp. This work lists about 50,000 technical journals in existence at any time during the half-century, and indicates British library holdings. It furnishes a means for identifying journals. There are certain peculiarities of alphabetization and of date designation. Until 1850 all four figures are given, beyond that only the last two. (Remember that 1817-30 means 1817-1930.)[6] The *World List* system of abbreviations for periodical titles has been recommended for international adoption.[7]

Two earlier lists of science journals, covering practically identical material, which are useful for data on publications of the period, are:

a. Bolton, Henry C. *A Catalogue of Scientific and Technical Periodicals 1665-1895, together with Chronological Tables and a Library Checklist.* (Second Edition.) Washington, D. C.: Smithsonian Institution, 1897. 1247 pp. (Smithsonian Miscellaneous Collections Vol. 40.)

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4. The *Bulletin of Bibliography* regularly reports "births and deaths" of journals.
5. Also New York: Academic Press.
6. *Op. cit.*, p. x.
7. See the *Chemical Abstracts* standard list of title abbreviations, recently adopted by the American Institute of Physics.

A subject index to the alphabetical listing enables one to select periodicals on "Physics" and other topics.

b. Scudder, Samuel H. *Catalogue of Scientific Serials of All Countries including the Transactions of Learned Societies in the Natural, Physical and Mathematical Sciences 1633-1876.* Cambridge, Mass.: Library of Harvard University, 1879. 358 pp.

This is geographically arranged by country and town.

For current periodicals, the most convenient lists are those indicating coverage, issued by the indexing and abstracting media such as *Chemical Abstracts, Physics Abstracts,* etc.

Typical journals.

There is a convenient *List of Periodicals of Physics Interest*[8] that indicates for each journal whether it is indexed in any of the "three abstracting services most frequently consulted by physicists . . . *Physics Abstracts, Chemical Abstracts,* and *Nuclear Science Abstracts,*" and the proportion of its contents devoted to physics. Accordingly, only representative journals need here be cited:[9]

Acoustical Society of America. Journal.
American Journal of Physics.
Annalen der Physik.
Astrophysical Journal.
Electronics.
Franklin Institute. Journal.
Helvetica Physica Acta.
Journal de Physique et le Radium.
Journal of Applied Mechanics.
Journal of Applied Physics.
Journal of Chemical Physics.
Journal of Scientific Instruments.
Nucleonics.
Optical Society of America. Journal.

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8. Compiled by Robert S. Bray, and available from U. S. Dept. of Commerce, Office of Technical Services, by number: PB 110082 ($.50).
9. Note how presence of a corporate name in the overall title affects alphabetization.

Philosophical Magazine.
Physica.
Physical Review.
Physical Society, London. Proceedings.
Physics Today.
Review of Scientific Instruments.
Reviews of Modern Physics.
Royal Society of London. Philosophical Transactions. Proceedings. (Series A)
Zeitschrift für Physik.

For useful data on United Kingdom scientific journals, see:

Royal Society of London. *A List of British Scientific Publications Reporting Original Work or Critical Reviews.* London: The Society, 1950. 95 pp.

Indexes and abstracts.

Annual indexes are appended to most of the bound volumes on library shelves, and publishers often issue combined indexes for several years output. These are useful. Noteworthy indexes are listed in:

a. Haskell, Daniel C. *A Check List of Cumulative Indexes to Individual Periodicals in the New York Public Library.* New York: The New York Public Library, 1942. 370 pp.

b. Ireland, Norma O. *An Index to Indexes; A Subject Bibliography of Published Indexes.* Boston: F. W. Faxon Company, 1942. 107 pp. (Unpublished indexes appear in her *Local Indexes*. . . Same publisher, 1947. 221 pp.)

Abstracting and indexing media for physics are listed in two installments[10] in the *American Journal of Physics,* as part of the abstracting study recently conducted jointly by the American Institute of Physics and the American Physical Society. (The list is also obtainable from the Office of Technical Services, U.S. Department of Commerce, as PB 99951, for seventy-five cents.) In other articles, Gray presents a preliminary overview

10. D. E. Gray and R. S. Bray, "Abstracting and Indexing Services of Physics Interest." *American Journal of Physics,* 18: 274-299, May 1950. Additions and corrections: *Ibid,* 18: 578-579, December 1950.

of abstracting;[11] summarizes the findings of the abstracting study;[12] and outlines recent developments.[13] The project has provided not only a comprehensive bibliography of indexing media, but a poll of physicists and librarians on the desirable features of such tools.

Another useful list is:

Besterman, Theodore. *Index Bibliographicus; Directory of Current Periodical Abstracts and Bibliographies.* (Third Edition.) Vol. 1: Science and Technology. New York: Columbia University Press, 1952. 63 pp. (UNESCO Publication No. 863.)

As the foregoing lists cover indexing in special areas very comprehensively, only the major indexing and abstracting services need be described:

Science Abstracts: For the physicist, the chief source of brief summaries (*i.e.,* abstracts) of articles is *Physics Abstracts,* in combination with *Electrical Engineering Abstracts* constituting *Science Abstracts* (Sections A and B respectively). This tool has been published since 1898 under the auspices of the British and American physical and electrical-engineering societies. The separate sections arrive from London monthly, and are arranged according to the Universal Decimal Classification System (summarized in the preliminary pages of each issue, and more fully in the January, 1949 issue). The U. D. C. number is printed at the head of each abstract on the right, and should not be confused with the consecutive item number (opposite) to which indexes refer. Physicists interested in "Electric Discharges" may turn to that section under "537.52" of *Physics Abstracts* each month; photocells, cathode-ray tubes, amplifiers and other topics in applied electricity will, similarly, be found under appropriate classification numbers in *Electrical Engineer-*

11. D. E. Gray, "Abstracts." *Physics Today,* 2 (No. 3): 20-25, March 1949.
12. D. E. Gray, "Physics Abstracting." *American Journal of Physics,* 18: 417-424, October 1950.
13. D. E. Gray, "Recent Developments in Physics Abstracting." *Physics Today,* 4 (No. 8): 18-20, August 1951.

ing Abstracts. However, it is believed[14] that not too much attention is paid to U. D. C. numbers by either librarians or physicists, who generally prefer to find subjects via contents pages or indexes. Prior to adopting the U. D. C. arrangement in 1942, *Physics Abstracts* had detailed semi-classified alphabetical indexes. At present, there are annual alphabetical-subject and author index issues, in addition to the monthly author lists. A list of journals covered was published in the first issue of 1953, with addenda in subsequent monthly prefaces.

Industrial Arts Index: Despite its title, *Industrial Arts Index* has rather high physics content. It presents an alphabetical subject arrangement, without abstracts, and possesses the characteristic cumulative feature of H. W. Wilson Company indexes. Thus, at intervals throughout the year, groups of prior issues will be gathered into one alphabet for convenient reference, with a final cumulation at year's end. An article may receive multiple listing under several relevant subject headings, but there is no author approach. This index, published since 1913, analyzes fully the contents of about 250 periodicals (listed in the prefatory pages of cumulative volumes).

Engineering Index: Annual volumes of *Engineering Index* are usually delayed by heavy publication tasks, but are paralleled by a selective card-index service on subscription basis. Arrangement is now alphabetical by major subjects and subheadings, linked by cross-references. (Before 1919, it was by classified subject.) Annual author indexes for the volumes since 1928 make finding articles by a particular individual easy. *Engineering Index* has been published since 1884, and selectively indexes the content of about 1,300 journals which are listed on prefatory pages. Each article receives a listing under but one subject heading, accompanied by an abstract. Many of the subjects, particularly electrical applications, are of interest to physicists as well as to engineers.

Applied Mechanics Reviews: This critical review medium indexes selected articles from four hundred magazines, etc., in

14. D. E. Gray, "Physics Abstracting." *American Journal of Physics*, 18: 420, October 1950.

twenty-eight countries, and began in 1948. It furnishes abstracts of important papers on theoretical and experimental aspects of fluid mechanics, solid mechanics, heat, gas dynamics, etc. Classified subject grouping is used, with annual author and subject indexes. The publisher is the American Society of Mechanical Engineers.

Nuclear Science Abstracts and *Bibliography of Technical Reports* are discussed under Government Publications.

Electronic Engineering Master Index and *Electronic Engineering Patent Index* are published by the Electronics Research Publishing Company, New York. The former indexes an important field of engineering which has physics ramifications. Its first volume (covering 1925-1945) was published in 1945. The latter commenced publication in 1946.

Physikalische Berichte: This virtually duplicates material found more conveniently in the English-language indexing media.

Chemical Abstracts[15]*:* Published by the American Chemical Society since 1907, this is without doubt the most comprehensive abstracting medium that exists in any field. Chemists rely upon it for information gleaned from thousands of periodicals throughout the world. Of particular physics interest are the sections on electronic and nuclear phenomena. The semimonthly issues have a broad classified arrangement, with author lists. Contents for previous years are rendered conveniently accessible by an impressive array of indexes, including decennial indexes which obviate consultation of the annual author and subject indexes for the years spanned. Small superior numbers (more recently letters) found in various indexes merely indicate how far down on the page an abstract appears. Symbol "P" is used for patent entries. The latest list of periodicals abstracted appears in Vol. 45 (1951), separately paged i—cclv. Its alphabetization is according to the *bold-faced portions* of the journal titles, these constituting standard abbreviations described (p. i.) as follows:

> Our authorized abbreviations were adopted years ago as an international
> A-I is of physics interest, including mathematical theory, atomics, etc.

15. The British counterpart is *British Abstracts, A, B and C.* Section

standard for chemistry by the International Union of Pure and Applied Chemistry. In the present revision of the List a few abbreviations have been altered to conform with recommendations made by the International Federation of the National Standardizing Associations, as suggested by UNESCO, and some other alterations have been made at the request of the American Institute of Physics, which, on the suggestion of Wallace R. Brode[16], has adopted our journal-name abbreviations and forms for use in its journals in the field of physics.

Meteorological Abstracts: This has been published monthly by the American Meteorological Society, Boston, since 1950.

Bibliographic Index: Beginning in 1938, this H. W. Wilson publication now appears semi-annually, with either an annual or larger (four-year) cumulation each December. It is a subject index to current bibliographies "including those published separately as books and pamphlets, and those published as parts of books, pamphlets and periodical articles." Although general in scope, it includes items of physics interest.

Other general indexing services useful on occasion to physics readers are the H. W. Wilson Company's *Readers' Guide to Periodical Literature, International Index to Periodicals, Education Index,* etc.[17] For translation listings, see Chapter VIII. For photography, etc., see Eastman Kodak's *Monthly Abstract Bulletin.*

Earlier material is spanned chronologically by the following trio:

a. Reuss, Jeremias D. *Repertorium Commentationum a Societatibus Litterariis Editarum.* Gottingae: Apud Henricum Dietrich, 1801-1821. 16 vols. Of special interest is Vol. 4: Physica (1805). Indexing of society publications is by classified subject, with an author index. The language of the article (including English) is used in its entry. (*See also* Thomas Young's great bibliography for parallel coverage.)

b. Royal Society of London. *Catalogue of Scientific Papers, 1800-1900.* London: C. J. Clay and Sons, 1867-1902; Cambridge, England: At the University Press, 1914-1925. 19 vols.

Subject Index: Vol. 1, Mathematics; Vol. 2, Mechanics;

16. See W. R. Brode, "Journal Abbreviations." *Physics Today,* 4 (No. 8): 4-5, August 1951.
17. The publisher issues several brochures listing and describing its various indexes and services, with specimen pages from many.

Vol. 3 (in two parts), Physics. Cambridge, England: At the University Press, 1908-1914. 3 vols. in 4.
This combination forms a monumental author and subject approach to articles in periodicals and transactions of societies for the whole nineteenth century. Fortunately for the physicist, the index volumes for his major fields of interest have been the first to be published. These are arranged by classified subjects, according to the *International Catalogue of Scientific Literature* schedules (outlined at beginnings of volumes and indexed at ends). The articles are arranged chronologically under subject. The index volumes have complete data (except title in full), and lists of journals covered.

c. *International Catalogue of Scientific Literature, 1901-1914/1916.* Published for the International Council by the Royal Society of London. London: Harrison, 1902-1919. 14 annual issues, each in 17 vols. While published, this was a science bibliography of truly mammoth proportions. Each of the seventeen annual volumes was devoted to a science, e.g., A - Mathematics; B - Mechanics; C - Physics; etc., classified according to the listed schedules, and with author and subject approaches to book and periodical literature. Incidentally, the French titles were duplicated in *Bibliographie Scientifique Française,* which began in 1902 and is still being published.

Reviews.

Unlike the indexing and abstracting media, which identify individual articles, review serials endeavor to synthesize important researches into a connected account of scientific progress. They represent further assistance to the physicist in his attempt to assimilate current material relevant to his subject field. Three general media are:

a. *Reviews of Modern Physics.* New York: American Institute of Physics, 1929 to date. This is a quarterly publication under sponsorship of the American Physical Society, and furnishes well-documented surveys of research in various areas. At the end of Vol. 22 there is an author-subject index for the set to 1950.

b. The Physical Society (London). *Reports on Progress in Physics.* London: The Society, 1934 to date. These are inter-

esting bibliographical accounts of yearly advance along many lines, including educational. Some articles even cover the whole development of a subject. Appended to Vol. 15 are cumulative author-subject indexes for 1934-1952, and there is a 78-page separately published *Cumulative Name Index of Volumes I-VII, 1934 to 1941.*

c. *Ergebnisse der Exakten Naturwissenschaften.* Berlin: Springer, 1922 to date. Its review monographs are well organized, illustrated and documented.

With the ever-rising flood of book and periodical literature, it becomes increasingly difficult for scientists and engineers to keep abreast of new developments, especially in fields that border their own. The recent appearance of special reviewing series is perhaps the most promising form of assistance. Some are:

Biophysics

a. *Progress in Biophysics and Biophysical Chemistry,* edited by J. A. V. Butler and J. T. Randall. Vol. 1- 1950- New York: Academic Press.

b. *Advances in Biological and Medical Physics,* edited by John H. Lawrence and Joseph G. Hamilton. Vol. 1- 1948- New York: Academic Press.

Cosmic rays

Progress in Cosmic Ray Physics, edited by J. G. Wilson. Vol. 1- 1951- New York: Interscience Publishers, Inc.

Electronics

Advances in Electronics, edited by L. Marton. Vol. 1- 1948- New York: Academic Press.

Geophysics

Advances in Geophysics, edited by H. E. Landsberg. Vol. 1- 1952- New York: Academic Press.

Mechanics

Advances in Applied Mechanics, edited by Richard von Mises and Theodore von Kármán. Vol. 1- 1948- New York: Academic Press.

See also Applied Mechanics Reviews.

Metal physics

Progress in Metal Physics, edited by Bruce Chalmers. Vol. 1- 1949- New York: Interscience Publishers, Inc.

Nuclear physics

a. *Annual Review of Nuclear Science.* Vol. 1- 1952- Stanford, Cal.: Annual Reviews, Inc. (Prepared under the supervision of the Committee on Nuclear Science of the National Research Council.)

b. *Progress in Nuclear Physics,* edited by O. R. Frisch. Vol. 1- 1950- London: Butterworth-Springer, Ltd.; New York: Academic Press. Characteristically, "this volume is intended to help both the nuclear physicist in finding information in fields adjacent to his own, and the other scientist in getting an introduction to some technique in nuclear physics which he may wish to use for his own purpose."

Advances in Physics is a separate quarterly supplement of the *Philosophical Magazine* (London) beginning with the January 1952 issue.

Readable and informative review articles are frequently featured in the *American Journal of Physics,* acquainting students and non-specialists with a subject (e.g., servomechanisms[18]) within relatively small compass. *See also* certain sources mentioned under Current Events and various treatises throughout the Topical Approach.

Societies.

Society publications represent scholarly contributions to research, and serve as valuable supplements to other books and journals. The most convenient guide to issuing agencies is the following:

National Research Council. *Handbook of Scientific and Technical Societies and Institutions of the United States and Canada.* (Fifth Edition.) Washington, D. C.: The Council, 1948. 371 pp. (Its *Bulletin,* No. 115, April 1948.)
For each society there are descriptive notes on its history, object, membership, publications, etc.

Learned societies (as well as universities, colleges, technical schools, etc.) are listed world-wide in the French *Index Generalis* and the German *Minerva.*

18. R. H. Bacon, "Servomechanisms." *American Journal of Physics,* 16: 79-92, February 1948.

Historical treatments include:

a. Ornstein, Martha. *The Role of Scientific Societies in the Seventeenth Century.* (Third Edition.) Chicago: University of Chicago Press, 1938. 308 pp.

b. Bates, Ralph S. *Scientific Societies in the United States.* New York: John Wiley and Sons, 1945. 246 pp.

Full-length histories of particular societies may be represented by:

Lyons, Sir Henry G. *The Royal Society, 1660-1940.* Cambridge, England: At the University Press, 1944. 354 pp.

The American Institute of Physics and its member societies (American Physical Society, Optical Society of America, Acoustical Society of America, Society of Rheology, and American Association of Physics Teachers) are described at length in the "A. I. P. 20th Anniversary issue" of *Physics Today,* 4 (No. 10): 12-27, October 1951.

For descriptive summaries of the National Academy of Sciences,[19] National Research Council,[19] Office of Scientific Research and Development, and other wartime scientific agencies, see *Journal of Applied Physics,* 14: 373-405, August 1943.

International organizations, such as the International Union of Pure and Applied Physics, are listed in:

Directory of International Scientific Organizations. Paris: United Nations Educational, Scientific and Cultural Organization, 1950. 224 pp. (UNESCO Publication No. 619.)

See also Brauer's *Forschungsinstitute.*

Early society publications may be traced by means of the Reuss' *Repertorium,* Royal Society *Catalogue,* and *International Catalogue,* supplemented by regional bibliographies such as:

a. Müller, Johannes. *Die Wissenschaftlichen Vereine und Gesellschaften Deutschlands im Neunzehnten Jahrhundert; Bibliographie ihrer Veroffentlichungen seit ihrer Begründung bis auf die Gegenwart.* Berlin: Behrend and Company, 1883-1917. 2 vols. in 3.

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19. *See also* D. E. Gray, "The National Academy of Sciences and the National Research Council." *Physics Today,* 5 (No. 1): 20-23, January 1952.

b. Deniker, Joseph, and Descharmes, René. *Bibliographie des Travaux Scientifiques (Sciences Mathématiques, Physiques et Naturelles) publiés par les Sociétés Savantes de la France.* Paris: Imprimerie Nationale, 1895-1922. Vol. 1 - Vol. 2, pt. 1, A - Sarthe.

Congresses.

For conference publications there is a compilation similar in function to the *Union List of Serials*:

International Congresses and Conferences 1840-1937; A Union List of Their Publications Available in Libraries of the United States and Canada, edited by Winifred Gregory. New York: The H. W. Wilson Company, 1938. 229 pp.

Substantial volumes have been published for various international physics conferences; for example, the following titles:

a. *Rapports présentés au Congrès International de Physique réuni à Paris en 1900 sous les auspices de la Société Française de Physique.* Paris: Gauthier-Villars, 1900-1901. 4 vols.

b. *Atti del Congresso Internazionale dei Fisici; 1927; Como, Pavia, Roma.* Bologna: Nicola Zanichelli, 1928. 2 vols.

c. *International Conference on Physics, London, 1934. Papers and Discussions.* Cambridge, England: At the University Press, 1935. 2 vols. (Vol. 1: Nuclear physics; Vol. 2: Solid state of matter.)

Other conferences that have issued proceedings include the several International Congresses for Applied Mechanics; the Conferences on Spectroscopy at the Massachusetts Institute of Technology; National Electronics Conferences; Optical Conventions in London; etc.

Government publications.

The United States Government issues several scientific periodicals, as well as an abundance of separate materials appearing irregularly in pseudo-serial form. The following will be found most helpful:

Boyd, Anne M., and Rips, Rae E. *United States Govern-*

ment Publications.[20] (Third Edition.) New York: The H. W. Wilson Company, 1949. 627 pp.

Of physics interest are the National Bureau of Standards' publications, such as the monthly *Journal of Research* and *Technical News Bulletin*; *Circulars* on a wide range of topics, e.g., Nos. 475 and 531 on electrical units; No. 470 on resistors; etc. The Bureau issues checklists[21] of its prior publications at intervals, and annual reports on its diversified activities. (For further discussion of standards in general, see Chapter V.)

Another governmental agency vitally linked with physics research and experimentation is the United States Atomic Energy Commission.[22] Because of secrecy requirements, only declassified and unclassified reports are available to the public, as follows: (a) Published in journals, e.g., in *Physical Review, Review of Scientific Instruments, Nucleonics;* (b) Sold as separates by the Office of Technical Services, Department of Commerce, Washington 25, D. C.; (c) Included in books of the National Nuclear Energy Series, published by McGraw-Hill Book Company; and (d) Consulted at AEC Depository Libraries, e.g., New York Public Library, Columbia University Library, and thirty-six others. Non-classified material appears in *Nuclear Science Abstracts*, issued semi-monthly by the Atomic Energy Commission, and "abstracting as completely and as promptly as possible the literature of nuclear science and engineering." (Its predecessor was *Abstracts of Declassified Documents,* vols. 1-2, July 1947-June 1948, with combined index.) A cumulative index to vols. 1-4 of *Nuclear Science Abstracts,* by author, subject, nuclide and report number, is supplemented by the subsequent annual, quarterly and individual indexes. The next multi-volume index will span vols. 5-10,

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20. *See also* K. N. Miller, *The Selection of United States Serial Documents for Liberal Arts Colleges.* New York: The H. W. Wilson Company, 1937. 364 pp.
21. See its Circular No. 460: *Publications of the National Bureau of Standards 1901 to June 30, 1947.* G. P. O., 1948. 375 pp; and *Supplementary List of Publications . . . July 1, 1947 to June 30, 1952.* G. P. O., 1952. 223 pp.
22. See D. E. Gray, "Dissemination of Technical Information by AEC." *Physics Today*, 4 (No. 11): 22-24, November 1951.

1951-1956. Abstracts give journal citations for articles, and the numbers of reports. Report numbers may be identified in the latest cumulated numerical index and its supplements, which disclose source and price. In issues from January 15, 1952 until June 30, 1953 (when temporarily omitted), *New Nuclear Data* appeared in *Nuclear Science Abstracts*, with quarterly and annual cumulations, in continuance of *Nuclear Data*, U. S. National Bureau of Standards Circular No. 499 plus 3 supplements.

In addition to non-classified AEC separates, the Office of Technical Services[23] disseminates technical reports[24] of civil and governmental research agencies. These are listed in its *Bibliography of Technical Reports,* which began publication in 1946 under the title *Bibliography of Scientific and Industrial Reports.* Monthly issues have a topical arrangement, e.g., Physics; Instruments; Electronics. Mimeographed reports may be ordered by P. B. (Publication Board) Number from the Office of Technical Services, Washington 25, D. C., but those in microfilm or photostat form should be ordered from the Library of Congress, Photoduplication Service, Washington 25, D. C. (Still others are obtainable from the issuing agency specified in the listing.) One may subscribe to the monthly *Technical Reports Newsletter* for selected abstracts. Besides subject indexes at ends of volumes, there is a time-saving numerical index for the first ten:

Special Libraries Association. Science-Technology Group. *Numerical Index to the Bibliography of Scientific and Industrial Reports, Vols. 1-10,*[25] *1946-1948.* New York: The Association, 1949. 522 pp.

Knowing the *P. B. No.* of a report, one may use the *P. B. No. Index* to locate its entry by volume and page in the large set.

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23. See D. E. Gray, "The Office of Technical Services of the Department of Commerce." *Physics Today,* 4 (No. 12): 24-26, December 1951.
24. See B. M. Fry, *Library Organization and Management of Technical Reports Literature.* Washington, D. C.: Catholic University of America Press, 1953. 140 pp.
25. For subsequent volumes, the Office of Technical Services issues a semi-annual *Numerical Index Supplement* showing the page on which a PB entry appears.

Furthermore, correlation indexes enable one to find BIOS, FIAT, etc., entries readily. For example, FIAT No. 874 on hydrogenation of ethylene oxide is found by reading "P. B. No. 80396" opposite "FIAT 874" on page 481 of the index. Then use the *P. B. No. Index* (page 345) to ascertain "Vol. 6, p. 1140" of the main set.

Starting with the year 1953, Technical Information Service, 15th and H Sts., N. W., Washington 5, D. C., offers a similar numerical *Index to PB Reports* listed in the *Bibliography of Technical Reports*, cumulating semi-annually and annually.

Patent literature is also of physics interest.[26] The United States Patent Office distributes patent descriptions called specifications, that are abstracted in the weekly *Official Gazette,* and are finally listed in the *Annual Index* by catch-title. Copies of patents may be purchased at twenty-five cents from the Commissioner of Patents, Washington 25, D. C., or examined at certain libraries.

Several bibliographical tools are useful for finding references to government documents:

a. *Document Catalog.* This comprehensive analytical catalog by subject, author and department was issued biennially from the 53rd through 76th Congress, and covers 1893-1940.

b. *Monthly Catalog.* One must consult it for the period since 1940 as a useful although briefer listing of the majority of government documents. The format has recently been improved for easier reference. Thus issuing agencies are now arranged alphabetically, and the monthly and annual indexes feature subjects rather than mere catch-titles. (Three supplements for the periods 1941-1942, 1943-1944, and 1945-1946 remedy certain omissions.)

c. *List of Selected United States Government Publications for Sale by the Superintendent of Documents.* This lists a few new items of wide appeal, semi-monthly.

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26. *See also* the following: American Association for the Advancement of Science, *The Protection by Patents of Scientific Discoveries.* New York: The Science Press, 1934. 40 pp.; a 35-page brochure obtainable from the Patent Office, U. S. Department of Commerce, entitled *General Information Concerning Patents*; and Radzinsky's *Making Patent Drawings.*

d. *Price Lists.* These itemize only documents still in print and on sale, for such subject areas as: Magnetism, engineering, etc. in No. 18; Electricity tests, weight standards in No. 64; Chemistry in No. 46. Price List No. 55 is devoted to the National Academy of Sciences,[27] National Museum, and Smithsonian Institution.

e. *Checklists.* Agencies often issue indexes of their own publications.

Symbols indicating availability of government publications are explained on *Monthly Catalog* covers; e.g., asterisks denote items sold by the Superintendent of Documents; single daggers direct inquiry to the issuing agencies; and large black dots indicate availability at depository libraries.

Using periodicals.

Although random scanning of journals sometimes yields relevant material, consulting the abstracts and indexes previously mentioned is a far more efficient procedure. Familiarity with subject heading techniques is of prime importance, and may be developed by: (1) acquisition of sufficient subject background for orientation purposes; and (2) examination and comparison of headings used in periodical indexing media. These indexes choose particular terms under which to list articles, with cross references from synonymous and related terms. Unfortunately, the choices vary among different media, as tabulated elsewhere.[28]

After doing some preliminary reading on a subject, one should prepare a list of likely headings to be searched, adding others as required. It is preferable to work from current volumes of indexes towards earlier ones, for this practice places emphasis upon recent material and may be conveniently stopped whenever enough items have been garnered, or when a comprehensive review article adequately summarizing prior research has been discovered. Attention should be given to all "*see*"

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27. See D. E. Gray, "The National Academy of Sciences and the National Research Council." *Physics Today*, 5 (No. 1): 20-23, January 1952.
28. R. H. Whitford and J. B. O'Farrell, "Use of a Technical Library." *Mechanical Engineering*, 70: 987-993, December 1948, especially pp. 989-990.

references (from inactive to chosen headings), and "*see also*" references (among related headings). Proceeding systematically and accurately, record selected entries on separate slips in the following manner for most general[29] purposes:

Page, Chester H. — Instantaneous power spectra. J. Appl. Phys., 23: 31-34, Jan. 1952. (N. B.: "23: 31-34" means volume 23, pages 31-34 inclusive.)[30]

A *book* entry might be:

Howe, Harley E. — Introduction to physics, 2nd ed., N. Y., McGraw-Hill, 1948. 599 pp.

2—Books

The separate publications known as books differ widely in size, shape, format, purpose, level of understanding, and comprehensiveness.

General.

As previously noted, books do not contain the latest work in any field, for they are selective summaries that may be two or three years behind current practice, even at publication time. They range from multi-volume encyclopedias to introductory texts, and cover many different aspects (historical, mathematical, educational, topical, etc.). Very frequently they are published as units of a *series,*[31] for example:

a. *Methuen's Monographs on Physical Subjects.* London: Methuen and Company; New York: John Wiley and Sons.

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29. For publishers' style requirements, however, see index under Technical Writing.

30. A few journals page each issue separately, in which case it is desirable to indicate issue number also; e.g., *Physics Today,* 1 (No.8): 6-14, December, 1948.

31. Most publishers' series of discrete books are usually scattered by subject throughout a library collection. A series note on catalog cards serves to locate units of series that are shelved together, e.g., the *M. I. T. Radiation Laboratory Series,* an integral set with overall index volume.

These are pocket-size compendia noted for clarity of presentation.

b. *International Series in Pure and Applied Physics.* New York: McGraw-Hill Book Company.

Parke[32] has made an interesting comparison of these lucid monographs with volumes of the *Handbuch der Physik.*

c. *Cambridge Monographs on Physics.* Cambridge, England: At the University Press.

These are "more substantial and comprehensive than the Series of Physical Tracts which they now supersede."

d. *Prentice-Hall Physics Series.* New York: Prentice-Hall, Inc.

e. *International Series of Monographs on Physics.* Oxford: At the Clarendon Press.

Advanced treatises for specialists appear in this authoritative collection.

f. *National Nuclear Energy Series.* New York: McGraw-Hill Book Company.

Authorized by the Atomic Energy Commission, this set records declassified atomic research in its non-military applications.

The foregoing series have been selected from among many possible examples on the basis of their diversified character. Advanced textbooks and treatises represented therein cannot be sharply differentiated, except that the former tend to be introductory teaching presentations, while the latter are well-documented comprehensive records possessing reference utility.

Interesting surveys[33] of current publishing conditions have been contributed by two leading technical publishers who are presidents of the McGraw-Hill Book Company and John Wiley and Sons, respectively. Mr. Benjamin laments that many specialized scientific books that should be published for the good of science cannot be accepted because of high printing cost and limited audience. Mr. Hamilton concurs, and draws a distinc-

32. N. G. Parke, *Guide to the Literature of Mathematics and Physics, including Related Works on Engineering Science,* pp. 53-56. New York: McGraw-Hill Book Company, 1947.

33. C. G. Benjamin, "What Price Scientific Books." *Physics Today,* 5 (No. 4): 23-26, April 1952; and E. P. Hamilton, "Engineering Literature." *Library Journal,* 77: 1939-1941, November 15, 1952.

tion between successive "editions" and "printings" that should be more universally observed:

> In the earlier days of publishing, the term "new edition" seems to have been used carelessly. Often a so-called new edition amounted to little more than a new printing, perhaps with minor corrections. Today we insist that a new edition means a really substantial revision. Some authors think that if they add a chapter and make a few corrections elsewhere their book might qualify as a new edition. With this viewpoint we disagree. We prefer to call such a book a corrected printing, and are willing to add a line on the title page to the effect that a new chapter has been included.

Bibliographies.

The term "bibliography" may be taken to denote any list of books and other printed materials, thus including lists associated with the publishing trade as well as those usually appended to research studies. A subject bibliography may be selective or comprehensive within set limits, and is most valuable when annotated and arranged by topical subdivision, although chronological and author arrangements are also employed.

An example of a bibliography of bibliographies[34] is:

Darrow, Karl K. *Classified List of Published Bibliographies in Physics 1910-1922.* Washington, D. C.: National Research Council, 1924. 102 pp. (Its *Bulletin,* Vol. 8, Pt. 5, No. 47, July 1924.)

Guides to reference books enable one to find physics material in the more general bibliographical tools. The following will prove extremely helpful on many occasions:

a. Winchell, Constance M. *Guide to Reference Books,* based on the . . . sixth edition by Isadore G. Mudge. (Seventh edition.) Chicago: American Library Association, 1951. 645 pp. *1st Supplement:* 1950-1952, by C. M. Winchell and Olive Johnson. A. L. A., 1954. 144 pp.

b. Roberts, A. D. *Introduction to Reference Books.* (Second Edition.) London: The Library Association, 1951. (Reprinted 1952.) 214 pp.

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34. *See also* T. Besterman, *A World Bibliography of Bibliographies.* (Second Edition.) London: The Author, 1947-1949. 3 vols. (Physics is covered in columns 2342-2350.) ***Bibliographic Index*** was cited earlier.

Special subject guides provide overall surveys, search techniques, and specific sources. An excellent guide for physics and related fields is:

Parke, Nathan G. *Guide to the Literature of Mathematics and Physics, Including Related Works on Engineering Science.*[35] New York: McGraw-Hill Book Company, 1947. 205 pp.

Parke emphasizes use of the literature, and devotes considerable attention to general principles of self-directed reading and learning. Chapters on searching book and periodical literature are followed by an extensive bibliography arranged by the topics of physics, mathematics and engineering combined within a single alphabet. This book and Parke's may very well be used together, each supplementing the other. Bordering fields are charted by many well-known guides,[36] as well as by an attractively designed bibliography:

Hawkins, Reginald R., editor. *Scientific, Medical, and Technical Books Published in the United States of America, 1930-1944.* Washington, D. C.: National Research Council, 1946. 1,114 pp. *1st Supplement:* 1945-1948. The Council, 1950. 514 pp. *2nd Supplement:* 1949-1952. The Council, 1953. 579 pp.

British books are listed in:

a. British Science Guild. *A Catalogue of British Scientific and Technical Books.* (Third Edition.) London: The Guild, 1930. 754 pp. This is a non-selective classified list of books in print as of September 1929.

b. Association of Special Libraries and Information Bureaux. *Select List of Standard British Scientific and Technical Books.* (Fourth Edition.) London: The Association, 1952. 72 pp.

Books in the English language (no matter where published) may be found by subject in the *Cumulative Book Index,* issued monthly by the H. W. Wilson Company (in continuation of its *United States Catalog* series). Whether a book originally listed is still obtainable may be ascertained from *Books in Print* which is an index volume to *Publishers' Trade List Annual,* a collec-

35. A second edition is in preparation at this writing.

36. Such as those for Chemistry included in the General Bibliography.

tion of the catalogs of American publishers.[37] Their most recent output is announced by descriptive leaflets sometimes called "blurbs," and by listings in *Publishers' Weekly.*

It should be noted that certain general bibliographical sources have some physics content, e.g., the *Standard Catalogs* (issued by the H. W. Wilson Company); the basic *A. L. A. Catalog 1926* plus its four supplements through 1949; and the following compilation:

Shaw, Charles B., compiler. *A List of Books for College Libraries.* (Second Preliminary Edition.) Chicago: American Library Association, 1931. 810 pp.; *Supplement, 1931-1938.* Chicago: The Association, 1940. 284 pp.

French and German publications of the war years are included in:

a. *French Bibliographical Digest. Science, No. 7: Physics.* New York: Cultural Division of the French Embassy, 1951. 87pp.
This presents significant French books on physics published 1940-1948.

b. Cummins, A. E., and Vince, S. *German Books on Chemical and Cognate Subjects [including Physics] Published 1939-1950.* (Second Edition.) London: Lange, Maxwell and Springer, Ltd., 1951. 102 pp.

Many other sources of foreign publications, such as the French *Biblio* and German *Bibliographie der Deutschen Bibliothek,*[38] are listed in Winchell.[39] (For translated works, see UNESCO's *Index Translationum.*)

Current annotated lists and reviews enable one to appraise publications. Entries in *Publishers' Weekly,* though brief, identify new books of scientific publishers in this country. *New Technical Books* is a bi-monthly periodical describing recent acquisitions of the New York Public Library's Science-Technology De-

37. For British publishers' books in print, see Whitaker's *Reference Catalogue of Current Literature.*
38. This prominently displays the title "Halbjahres Verzeichnis." However, the well-known *Halbjahrsverzeichnis...des Deutschen Buchhandels,* which ceased publication in 1944, is continued by *Jahresverzeichnis des Deutschen Schriftums.*
39. *Op cit.* pp. 23-55.

partment, whose Chief compiles monthly and annual book sections for *Library Journal.* The *United States Quarterly Book Review,* "published for the Library of Congress by Rutgers University Press," includes science books. Those of wide appeal receive listing in the *Booklist,* published semi-monthly by the American Library Association. *Subscription Books Bulletin* reviews sets. Selected British publications appear in the monthly *British Book News* and quarterly *ASLIB Book-List.* To keep thoroughly informed, one should scan the book reviews that appear in certain journals, notably *American Journal of Physics, Review of Scientific Instruments, Physics Today, Science News Letter, Nature, Science,* etc. (After an appreciable time lapse, excerpts from reviews appear in *Technical Book Review Index,* which also serves as a new-book checklist.)

For bibliography of early works one may turn to:

Young, Thomas. *A Course of Lectures on Natural Philosophy and the Mechanical Arts.* London: Joseph Johnson, 1807. 2 vols.

This first edition includes (Vol. 2, pp. 87-520) a selective subject bibliography of 20,000 book and periodical references systematically collected through 1805. It was omitted in a later edition dated 1845, but is still valuable. Crew declares:

> No serious minded student of physics will fail to make the acquaintance of Dr. Thomas Young; for he is the last man, unless one includes Whewell and Helmholtz, of the race that knew everything that was to be known—the group that includes Aristotle, Leonardo da Vinci, Stevin, Galileo, Descartes, Huygens, Franklin.[40]

Old works, as they pass through book auctions, may be listed in *American Book-Prices Current* which is published by R. R. Bowker Co. and has collective indexes. The Henry Sotheran Company's *Bibliotheca Chemico-Mathematica* is a pretentious multi-volume catalog of scientific classics, with interesting comments on their contents and special features. Extensive card catalogs of long-established libraries may be consulted for older printed material, especially when books are chronologically grouped for major subjects. Finally, one may use earlier bibliographies, such as:

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40. H. Crew, *The Rise of Modern Physics,* pp. 245-246. (Second Edition.) Baltimore: Williams and Wilkins Company, 1935.

John Crerar Library. *A List of Bibliographies of Special Subjects.* Chicago: The Library, 1902. 504 pp.

Dissertations.

An indispensable tool for tracing theses is:

Palfrey, Thomas R., and Coleman, Henry E. *Guide to Bibliographies of Theses, United States and Canada.*[41] (Second Edition.) Chicago: American Library Association, 1940. 54 pp. Its three parts are: General lists of dissertations in all fields; Lists in special fields; Institutional lists.

Two general lists supplement each other chronologically:

a. Library of Congress. *List of American Doctoral Dissertations Printed in 1912 to 1938.* Washington, D. C.: Government Printing Office, 1913-1940. 26 vols.
In this discontinued record, emphasis was placed upon printed form rather than mere acceptance.

b. Association of Research Libraries. *Doctoral Dissertations Accepted by American Universities, 1933-34* to date. New York: The H. W. Wilson Company, 1934 to date.
Printing is not a criterion for inclusion.

In addition, one should consult the Palfrey and Coleman section on "Sciences" for the rather complicated array of acceptances for the period 1898-1933 during which listing occurred in *Science, School and Society,* and the National Research Council's *Reprint and Circular Series.*

Dissertation Abstracts (Formerly Microfilm Abstracts) lists dissertations and monographs available in microfilm form through University Microfilms, Ann Arbor, Michigan.

Using books and libraries.

Books are arranged on library shelves according to a classification scheme (Dewey, Library of Congress, etc.) so as to group books on a subject together, as well as in relative sequence. Call numbers are printed on books and catalog cards for identification and shelving purposes. The library's card

41. For additions and corrections, see R. P. Rosenberg, "Bibliographies of Theses in America." *Bulletin of Bibliography,* 18: 181-182 and 201-203, September-December 1945 and January-April 1946.

catalog serves as an index to its book holdings, but must be supplemented with published indexes that analyze periodical contents, etc. Its form is usually "dictionary," i.e., subject,[42] author and title cards in one alphabet, but some libraries favor separated or classified files. It should be noted that books are generally given an added entry under title only when it is distinctive, e.g., *Hidden Hunger* (a book on vitamins). Cards bear standardized bibliographical information, and are alphabetized according to definite filing rules with respect to word by word sequence (electron optics before electronics); omission of initial articles; grouping of *Mac* . . . variants, etc. Helpful clues to further literature are provided in the form of bibliography notes and cross reference cards. General reference works should not be overlooked.

To reveal more material beyond local holdings, such tools as the *Cumulative Book Index* may be consulted. Under certain restrictions, items may sometimes be examined at or borrowed[43] from nearby libraries, whose resources are indicated in union lists, and surveys like:

a. *Special Library Resources.*[44] New York: Special Libraries Association, 1941-1947. 4 vols.

b. Downs, Robert B. *Resources of New York City Libraries; A Survey of Facilities for Advanced Study and Research.* Chicago: American Library Association, 1942. 442 pp.

Periodical article reprints are often available from the author or his affiliated group, and photocopies of books and articles are obtainable from sources listed in:

Raymond, J. G. *Directory of Microfilm Services in the United States and Canada.* (Revised Edition.) New York: Special Libraries Association, 1947. 30 pp.

This lists local facilities (e.g., Columbia University Library; New York Public Library) and a national microfilm and photo-

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42. Subject headings are standardized, possibly according to the Library of Congress List, supplemented by M. J. Voigt, *Subject Headings in Physics.* Chicago: American Library Association, 1944. 151 pp.
43. See "General Interlibrary Loan Code 1952." *College and Research Libraries,* 13: 350-358, October 1952.
44. *See also* the latest *Special Libraries Directory* published by the Association.

stat service very extensively used, viz., Copying Service of the United States Department of Agriculture Library, Washington 25, D. C.

Some libraries will even, for nominal fees, prepare translations, bibliographies, abstracts, etc. Further material on efficient use of library collections and facilities may be found among the books listed in the General Bibliography.

CHAPTER III

HISTORICAL APPROACH
History and Current Events

Whenever information concerning past events is sought, the "Historical Approach" is indicated. One consults retrospective accounts of the development of physics among the natural sciences, or turns to more specialized versions. Current summaries are also available.

Intrinsically, any historical treatment embraces considerable biographical data. Accordingly, the books cited may be used as sources of such information by scanning their indexes. For topics of inquiry distinctly biographical in flavor rather than chronological, however, see Chapter IV.

Overview

Physics had its origins in the early Greek schools of thought which were devoted to the description of the fundamental nature and substance of the universe. These explanations, although fanciful and imaginative, have been credited with harboring the germ of the modern atomic and other theories. However, the beginning of physics as an experimental science is conceded to date from the close of the sixteenth century, when Galileo Galilei dared to base his conclusions on observed data instead of Aristotelian intuitive dicta. The succeeding centuries yielded great cumulative advance in physics under the all-embracing appellation, "Natural Philosophy," for only comparatively recently has physics been so known. The name modern physics (as distinguished from classical physics) is usually applied to the new atomic physics which began with the discovery of X-rays by Roentgen in 1895 and received great impetus from Planck's proposal of discrete quanta of radiation four years afterwards.

Without an adequate understanding of the past, the present cannot be fully appreciated. Intelligent grasp of today's know-

ledge in any field depends largely on a realization of the multifarious paths along which progress was made, the interrelationships of diverse lines of activity, and the gradual synthesis of successive findings and achievements. As Chalmers states:

> The historical approach towards any branch of scientific study possesses not only intrinsic interest; as a practical educative method it undoubtedly has distinct merits. It provides the easiest path towards the ready understanding of modern knowledge and opinion. However involved and abstruse any subject may appear in its modern dressing, it remains true in every case that it has been built up from simple foundations, from elementary observations made in past generations and the natural cogitations which they inspired in successive minds.[1]

The late Lloyd W. Taylor[2] was a foremost proponent of the idea that textbooks designed for regular courses in college physics should feature considerable historical material. Unfortunately, the only students whose thoughts are directed along historical lines seem to be the non-physics majors, via their "science survey" courses. Blüh maintains that all need such enlightenment:

> A modern Erasmus, in a present-day *In Praise of Folly,* would probably feel inclined to direct some of his critical remarks against men of science who demonstrate forcefully the necessity of a scientific education for everyone, but seem to be blind to the equal need of a broad education for themselves. The historical approach, for example, so widely advocated and propagated in the teaching of natural science as a cultural element in general education is only applied to the nonscientist, while the professional education of the scientist makes no effort to concern itself with historical considerations.[3]

I. B. Cohen urges use of interesting historical material and cites many sources in his article, "A Sense of History in Science" (*American Journal of Physics,* 18: 343-359, September 1950).

Guides

The reading of historical accounts becomes more meaningful when one is acquainted with compilation methodology, as related by a master chronicler:

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1. T. W. Chalmers, *Historic Researches,* p. 1. New York: Charles Scribner's Sons, 1952.
2. See his *Physics; the Pioneer Science.*
3. O. Blüh, "The History of Physics and the Old Humanism." *American Journal of Physics,* 18: 308-311, May 1950.

Sarton, George. *A Guide to the History of Science.* Waltham, Mass.: Chronica Botanica Company, 1952. 316 pp. Three introductory essays on "Science and Tradition" are followed by an extremely useful literature guide, expanded from that earlier appended to the author's *Study of the History of Science* (1936). Some of the sections of this 236-page bibliography are: Scientific methods and philosophy of science; Science and society; National academies and national scientific societies; Treatises and handbooks on the history of science; History of special sciences; Journals and serials concerning the history and philosophy of science; Institutes, museums, libraries; International congresses.

Chronologies.

A most comprehensive chronological arrangement of 13,000 scientific discoveries and inventions from 3500 B. C. to the year of publication is:

Darmstaedter, Ludwig. *Handbuch zur Geschichte der Naturwissenschaften und der Technik in Chronologischer Darstellung.* (Zweite Auflage.) Berlin: Springer, 1908. 1262 pp. There are name and subject indexes to the brief descriptive items.

Another useful set of chronological tables is:

Auerbach, Felix. *Geschichtstafeln der Physik.* Leipzig: J. A. Barth, 1910. 150 pp.

Its four parts are: (1) Chronological table from 650 B. C. to 1900 A. D. giving important scientific discoveries, with year and physicist's name; (2) Chronological table of important physics books with year, author and place of publication from 350 B.C. to 1900 A.D.; (3) Chronological table of physicists, with dates of birth and death, from Pythagoras (560 to 490 B. C.) to Drude (1863-1906); and (4) Alphabetical index to the first part. Note that a later book[4] by Auerbach carries his tables of scientific discoveries and physicists through 1923.

Chronological tables are often appended to historical treatments, as noted throughout this chapter.

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4. F. Auerbach, *Entwicklungsgeschichte der Modernen Physik.* Berlin: Springer, 1923. 344 pp.

Bibliographies.

Relevant books in an outstanding library collection are listed in the following series:

John Crerar Library. *A List of Books on the History of Science.* Chicago: The Library, 1911. 297 pp.

First Supplement: 1917. 139 pp.

Second Supplement: Parts I-VI (1942-1946), of which Part IV (1944) is for Physics, 12 pp.

Other extensive bibliographical lists on the history of science may be found in Sarton's *A Guide to the History of Science,* noted before; and appended to the books by Pledge and Sedgwick cited under Science Histories, below.

In a particular library, historical treatments may be found under the headings "Physics — History" and "Science — History" in the card catalog. New books are listed in the *Cumulative Book Index.*

Historical Accounts

Books dealing exclusively with physics are of greatest interest to the users of this guide. However, it will be found necessary to supplement the relatively short histories of physics with the longer works available on the general history of science.

Physics histories.

Four recent books provide readable surveys:

a. Chase, Carl T. *The Evolution of Modern Physics.* New York: D. Van Nostrand Company, 1947. 203 pp.

b. Laue, Max von. *History of Physics.* New York: Academic Press, 1950. 150 pp.

c. Wilson, William. *A Hundred Years of Physics.* London: Gerald Duckworth and Company, 1950. 319 pp.
This outlines electromagnetic, quantum, relativity and other theories since 1840.

d. Chalmers, Thomas W. *Historic Researches; Chapters in the History of Physical and Chemical Discovery.* New York: Charles Scribner's Sons, 1952. 288 pp.
The chapters report research concerning friction, mechanical equivalent of heat, electro-dynamics, molecular physics, con-

duction of electricity through liquids and gases, X-rays, etc. They show "not only who made the discovery or formulated the theory—but how he came to make it and against what background of contemporary thought and achievement it was made." Biographical sketches appear on pp. 259-274.

Less recent but well-known presentations are:

a. Crew, Henry. *The Rise of Modern Physics.* (Second Edition.) Baltimore: Williams and Wilkins Company, 1935. 434 pp.
A lucid historical account of physics since the Renaissance, it combines subject and chronological approaches, stressing interrelationships.

b. Buckley, H. *A Short History of Physics.* (Second Edition.) London: Methuen and Company, 1929. 263 pp.
Like Wilson's book above, it is constructed upon the framework of successive physical theories, such as planetary, atomic, kinetic and quantum.

c. Cajori, Florian. *A History of Physics.* (Revised Edition.) New York: The Macmillan Company, 1929. 424 pp.
Chronologically arranged throughout, it prints physicists' names in bold face type. The final chapter (pp. 387-406) traces the evolution of various physical laboratories.

Among noteworthy German references are:

a. Ramsauer, Carl. *Grundversuche der Physik in Historischer Darstellung.* Vol. 1. Berlin: Springer, 1953. 189 pp.

b. Hoppe, Edmund. *Geschichte der Physik.* Braunschweig: Friedrich Vieweg und Sohn, 1926. 536 pp.

c. Poggendorff, Johann C. *Geschichte der Physik.* Leipzig: J. A. Barth, 1879. 937 pp.

Science histories.

Histories of physics *per se* may be supplemented with more general chronicles, which have the advantage of showing the relationship with science as a whole. Some well-written single volume works are:

a. Dampier-Whetham, William C. *A History of Science and its Relations with Philosophy and Religion.* (Fourth Edition.) Cambridge, England: At the University Press, 1949. 527 pp.

b. Jeans, Sir James H., and Grant, P. J. *The Growth of Physical Science.* (Second Edition.) Cambridge, England: At the University Press, 1951. 364 pp.
The chapter headings of this interesting work are: Remote beginnings; Ionia and early Greece; Science in Alexandria; Science in the dark ages; Birth of modern science; Century of genius; The two centuries after Newton; The era of modern physics.

c. Taylor, F. Sherwood. *A Short History of Science and Scientific Thought.* New York: W. W. Norton and Company, 1949. 368 pp.
"Readings from the great scientists from the Babylonians to Einstein" appear at ends of chapters.

d. Pledge, Humphry T. *Science since 1500; A Short History of Mathematics, Physics, Chemistry, Biology.* London: His Majesty's Stationery Office, 1939. 357 pp.
This coordinates work of leading scientists, and has interesting charts and maps on the accuracy of measurements, the connection of master and pupil, the tracks of science, and the birthplaces of scientists. There is a bibliographical note (pp. 326-329) on the literature of the history of science.

e. Sedgwick, William T.; Tyler, H. W.; and Bigelow, R. P. *A Short History of Science.* (Revised Edition.) New York: The Macmillan Company, 1939. 512 pp.
Its format and typography are very attractive. An interesting chronological table (pp. 472-486) lists important names and events in the history of science and civilization in parallel columns: "Science" vs. "General History, Literature, Art, etc." A bibliography of reference books on the history of science is appended, pp. 487-500.

The early period from the fourteenth through nineteenth centuries is well spanned by the following books that stress scientific attitude:

a. Butterfield, Herbert. *The Origins of Modern Science, 1300-1800.* London: G. Bell and Sons, 1949. 217 pp.

b. Singer, Charles. *A Short History of Science in the Nineteenth Century.* Oxford: At the Clarendon Press, 1941. 399 pp.

Lecture series are often permanently recorded in print. There is no more interesting means of communicating historical information than through sponsored lecture series, especially when

the lecturers are noted scientists familiar with all phases of their subject, and gifted with powers of lucid exposition. As noteworthy examples, two such programs may be mentioned:

a. *Background to Modern Science.* Ten lectures at Cambridge arranged by the History of Science Committee 1936, by F. M. Cornford, Sir W. Dampier, Lord Rutherford, W. L. Bragg, F. W. Aston, Sir A. S. Eddington, J. A. Ryle, G. H. F. Nuttall, R. C. Punnett, J. B. S. Haldane. Edited by Joseph Needham and Walter Pagel. New York: The Macmillan Company, 1940. 243 pp.

The roster includes distinguished participants in scientific advance, 1895 to 1935. For example, Rutherford's "Forty Years of Physics" (pp. 49-74) sketches important work in radioactivity and atomic structure; Aston outlines "Forty Years of Atomic Theory" (pp. 93-114).

b. Woodruff, Lorande L., editor. *The Development of the Sciences.* (First and Second Series.) New Haven, Conn.: Yale University Press, 1923-1941. 2 vols.

These collections of public lectures at Yale University include sections on physics.

For more comprehensive treatment than provided by the various single volumes of standard length so far enumerated under Physics Histories and Science Histories, one turns to works-in-progress of the master historians. So ambitious is the scale of some of their works that completion must undoubtedly be left to successors. Most impressive in this respect is:

Sarton, George. *Introduction to the History of Science.* Published for the Carnegie Institution of Washington. Baltimore: Williams and Wilkins Company, 1927-1948. 3 vols. in 5.

This awe-inspiring treatise, covering meticulously the unfolding of science from Homer's time, is characterized by Sarton as an overall guide:

> Critics who like to dispose of another man's work with a single label, should not call mine a dictionary or a bibliography but rather, if they please, a map—a scientific map with full indication of the sources.[5]

The author further states that he emphasizes interrelationships,

5. *Op. cit.*, Vol. 2, Pt. 1, p. vii.

and provides a framework rather than the whole account. The work is arranged in half-century periods; then by subject field. It is not intended to be read through. Sarton suggests, instead, reading the survey in the introductory chapter and the first chapter of each book, and consulting other sections when necessary for details. Coverage at present is: (Vol. 1) From 9th century B. C. through 11th century; (Vol. 2, Pt. 1) 12th century; (Vol. 2, Pt. 2) 13th century; (Vol. 3) 14th century.

The foregoing should not be confused with the author's initial volume of a new series:

Sarton, George. *A History of Science; Ancient Science through the Golden Age of Greece.* Cambridge, Mass.: Harvard University Press, 1952. 646 pp.

Sarton good-naturedly explains why he has undertaken still another multi-volume set:

> Many years ago, soon after the publication of volume 1 of my *Introduction*, I met one of my old students as I was crossing the Yard, and invited him to have a cup of coffee with me in a cafeteria of Harvard Square. After some hesitation, he told me, "I bought a copy of your *Introduction* and never was so disappointed in my life. I remembered your lectures, which were vivid and colorful, and I hoped to find reflections of them in your big volume, but instead I found nothing but dry statements, which discouraged me." I tried to explain to him the purpose of my *Introduction*, which was severe and uncompromising; a great part of it was not meant to be read at all but to be consulted, and I finally said, "I may be able perhaps to write a book that pleases you more."
>
> Ever since, I have often been thinking of this book which reproduces not the letter but the spirit of my lectures.[6]

Other comprehensive works include:

a. Wolf, A. *A History of Science, Technology, and Philosophy in the 16th and 17th Centuries.*[7] New York: The Macmillan Company, 1935. 692 pp.;

. . . *in the Eighteenth Century.*[7] New York: The Macmillan Company, 1939. 814 pp.

This superbly illustrated set is arranged by fields of science, and

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6. *Op. cit.*, p. vii.
7. New editions, with some corrections and later references, have been prepared by Douglas McKie. (London: George Allen and Unwin, Ltd., 1950-1952.)

has sections on scientific instruments of the times. Wolf champions the breadth of outlook recognized as essential by modern educators in stating:

> An encyclopaedic enterprise like the present may appear to be an anachronism in an age of extreme specialization. It is widely recognized, however, that the tendency toward a narrow specialism has already gone too far. The contemporary close relationship of science and philosophy, and the growing interest in the history and development of science, may be regarded as evidence of a growing recognition of the need of a wider outlook.[8]

b. Thorndike, Lynn. *History of Magic and Experimental Science.* New York: The Macmillan Company (Vols. 1-2); Columbia University Press, 1923-1941. 6 vols.

The inclusion of "magic" in this extremely well-documented treatise is explained by Thorndike as follows:

> My idea is that magic and experimental science have been connected in their development; that magicians were perhaps the first to experiment; and that the history of both magic and experimental science can be better understood by studying them together.[9]

Coverage is as follows: (Vols. 1-2) First thirteen centuries; (Vols. 3-4) 14th and 15th centuries; and (Vols. 5-6) 16th century.

c. Brunet, Pierre, and Mieli, Aldo. *Histoire des Sciences; Antiquité.* Paris: Payot, 1935. 1224 pp.

This first volume covers the period from prehistoric to 750 A. D., in a treatise planned to extend eventually to the middle of the 19th century. It includes extracts from less known as well as most noted men of ancient times. Chronological tables (pp. 1111-1123) show the time relation of "savants" in various fields with non-scientific events. A general bibliography (pp. 1124-1147) lists materials available in the history of ancient science.

Finally, no itemization of general histories of science would be complete without mention of the classic overview of scientific thought:

Whewell, William. *History of the Inductive Sciences from*

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8. *Op. cit.*, [Vol. 1], p. xxv.
9. *Op. cit.*, Vol. 1, p. 2.

the Earliest to the Present Time. (Third Edition.) New York: D. Appleton and Company, 1858. 2 vols.

As Macfarlane states:

> In 1837 Whewell finished the first part of his *History of the Inductive Sciences.* In this book he notes the *epochs* when the great steps were made in the principal sciences, the *preludes* and the *sequels* of these epochs, and the way in which each step was essential to the next. He attempts to show that in all great inductive steps the type of the process has been the same. The prominent facts of each science are well selected and the whole is written with a vigor of language and a facility of illustration rare in the treatment of scientific subjects.[10]

Special histories.

It will be helpful to indicate some of the areas of physics for which specialized historical accounts are available:

Atomism

Gregory, Joshua C. *A Short History of Atomism; from Democritus to Bohr.* London: A. and C. Black, Ltd., 1931. 258 pp.

On pp. 249-252 appears a chronological summary of important events in the history of atomism since 420 B. C.

Elasticity

a. Todhunter, Isaac. *A History of the Theory of Elasticity and of the Strength of Materials from Galilei to the Present Time,* edited and completed by Karl Pearson. Cambridge, England: At the University Press, 1886-1893. 2 vols. in 3.

b. Timoshenko, Stephen. *History of Strength of Materials with a Brief Account of the History of Theory of Elasticity and Theory of Structures.* New York: McGraw-Hill Book Company, 1953. 452 pp.

Electricity; Magnetism

This field boasts more histories than any other. A chronological listing is provided by:

National Electrical Manufacturers Association. *A Chronological History of Electrical Development from 600 B. C.* New York: The Association, 1946. 106 pp.

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10. A. Macfarlane, *Lectures on Ten British Physicists of the Nineteenth Century,* p. 89. New York: John Wiley and Sons, 1919.

Well-documented accounts of the development of electrical theory are:

a. Whittaker, Sir Edmund T. *A History of the Theories of Aether and Electricity.* (Revised Edition.) [Vol. 1]: The Classical Theories. New York: Philosophical Library, 1951. 434 pp.

Having issued this revision of his interesting survey, originally published 1910, the author contemplates a second volume on "the origins of relativity and quantum theory, and their development since 1900."

b. Benjamin, Park. *A History of Electricity (The Intellectual Rise in Electricity) from Antiquity to the Days of Benjamin Franklin.* New York: John Wiley and Sons, 1898. 611 pp.

c. Daujat, Jean. *Origines et Formation de la Théorie des Phénomènes Électriques et Magnétiques.* Paris: Hermann et Cie., 1945. 3 vols.

Volume coverage is: (Vol. 1) Antiquity and Middle Ages; (Vol. 2) 17th Century; and (Vol. 3) 18th Century.

See also Mottelay's great bibliographical history.

Popular historical narratives include:

a. Miller, Dayton C. *Sparks, Lightning, Cosmic Rays; An Anecdotal History of Electricity.* New York: The Macmillan Company, 1939. 192 pp.

This embodies lecture material and demonstration apparatus used at the Christmas week lectures for young people at the Franklin Institute. (Cf. the similar series at the Royal Institution.)

b. Greenwood, Ernest. *Amber to Amperes; The Story of Electricity.* New York: Harper and Brothers, 1931. 332 pp.

c. Still, Alfred. *Soul of Amber; The Background of Electrical Science.* New York: Murray Hill Books, Inc., 1944. 274 pp.

d. Still, Alfred. *Soul of Lodestone; The Background of Magnetical Science.* New York: Murray Hill Books, Inc., 1946. 233 pp.

Heat; Energy

a. Mott-Smith, Morton C. *The Story of Energy.* New York: D. Appleton-Century Company, 1934. 306 pp.

Its purpose (p. vii) is "to trace the story of man's conquest of energy, to describe the scientific discoveries that made it possible, and the chief ways that energy is applied to useful purposes." Steam engine cycles, theories of heat, conservation of energy, entropy, etc., are treated.

b. Gregory, Joshua C. *Combustion from Heracleitos to Lavoisier.* London: Edward Arnold and Company, 1934. 231 pp.

c. Ellis, Oliver C. de C. *A History of Fire and Flame.* London: The Poetry Lovers' Fellowship, 1932. 436 pp.

An unusual book, but "the work of one who is both scientist and poet; and thus it includes in its rich and vivid discussion the twofold majesty of Fire — its majesty in material events, and its majesty in the thought of man."[11]

Mechanics

The outstanding classic is:

Mach, Ernst. *The Science of Mechanics; A Critical and Historical Account of its Development.* (Fifth English Edition, translated from the ninth German edition.) La Salle, Ill.: The Open Court Publishing Company, 1942. 635 pp.

Noted as a lucid developmental account conducive to more complete understanding of the principles of mechanics, it includes a chronological table of important early works, pp. 617-619.

Other summaries in English are:

a. Girvin, Harvey F. *A Historical Appraisal of Mechanics.* Scranton, Pa.: International Textbook Company, 1948. 275 pp.

b. Ray, David H. *A History of Mechanics.* Lancaster, Pa.: The Author, 1910. 147 pp.

There is a chronological table on pp. 134-135 listing important contributions.

Foreign language presentations include:

a. Lange, Ludwig. *Die Geschichtliche Entwickelung des Bewegungsbegriffes...* Leipzig: Wilhelm Engelmann, 1886. 141 pp.

b. Dugas, René. *Histoire de la Mécanique.* Neuchatel: Editions du Griffon, 1950. 649 pp.

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11. *Op. cit.*, p. xi.

Optics; Color

a. Hoppe, Edmund. *Geschichte der Optik.* Leipzig: J. J. Weber, 1926. 263 pp.

This covers from 5,000 B. C. to the period of the quantum theory, and has an extensive bibliography, pp. 236-251.

b. Mach, Ernst. *The Principles of Physical Optics; An Historical and Philosophical Treatment.* London: Methuen and Company, 1926. 324 pp.

The author states (p. vii):

> I have endeavoured to show, from a critical and psychological standpoint, how the ideas concerning the nature of light have been moulded at the hands of prominent individual workers, what transformations these ideas have had to undergo on account of the revelation of new facts and by reason of the views associated with them, and how the general concepts of optics develop from these.

c. Halbertsma, K. T. A. *A History of the Theory of Colour.* Amsterdam: Swetz and Zeitlinger, 1949. 267 pp.

Sound

Miller, Dayton C. *Anecdotal History of the Science of Sound.* New York: The Macmillan Company, 1935. 114 pp.

Current events.

To keep abreast of current scientific developments one scans the regular and science sections of the *New York Times* and other newspapers, a chronological key to all being furnished by the *New York Times Index;* and reads the appropriate periodicals, whose contents are indexed as described in Chapter II. These range from the popular *Science News Letter, Scientific American,* and *Popular Science Monthly,* to the standard journals, *Science,* and *Nature.* More specialized are *Journal of Applied Physics, Physics Today, Optical Society of America Journal,* and countless others. For the history of science there is Sarton's international review called *Isis,* and also the British *Annals of Science.* General review serials (like *Reviews of Modern Physics*), and specialized media (such as *Advances in Electronics*) have previously been cited. Shorter yearly reviews of physics developments may be found in the annual supplementary volumes to the *Americana* and other encyclopedias, as

well as in journal résumés.[12] Overview articles by distinguished scientists are appended to the *Annual Report* of the Smithsonian Institution.

Summary

Full appreciation of physics as a cultural subject requires historical perspective. Background literature has been discussed, ranging from relatively short narratives of physics or general science to monumental treatises. Many special fields have their own historical accounts, often overlooked among the larger body of technical material which they nevertheless clothe with reality. Finally, the record is brought to date by mentioning sources of current events, from which will be selected the items of historical tomes yet to be written.

12. Notably the series, "Physics in 19—," in *Journal of Applied Physics*, vols. 11-16, 1940-1945, by T. H. Osgood; and vols. 18-19, 1947-1948, by P. Morrison. (For page location, consult volume subject indexes under "Physics in...") *See also*, J. R. Oppenheimer, "The Age of Science: 1900-1950." *Scientific American*, 183: 20-23, September 1950, followed by ten field résumés, e.g., *Physics*, by Max Born, pp. 28-31.

CHAPTER IV

BIOGRAPHICAL APPROACH
Biography and Source Material

This chapter reviews sources of biographical data, both current and retrospective. Because personal writings reveal human traits and scientific outlook beyond mere subject content, collected works and source extracts have been placed after the strictly biographical material.

Overview

The introduction to the previous chapter applies equally well to the present one. Individuals, of course, are the makers of science history, which is the record of their achievements among their fellows against world backgrounds. Hence historical narratives are rich in biographical detail, and biographies shed interesting sidelights on history. Collected writings and excerpts fulfill a similar function:

> . . . It is doubtful if any description brings out the scientific outlook of a period, or the experimental handicaps under which the foundations of the subject were laid, as forcibly as do the original papers. Furthermore the experimental difficulties, precautions, corrections, and incidental technique which have been found necessary for the attainment of extreme accuracy are nowhere so clearly shown as in the description of the investigators themselves.[1]

Collective Biography

In a general or preliminary search for relatively brief biographical data, one turns first to the books that deal with more than one scientist.

Encyclopedias.

The most comprehensive biographical undertaking for scientists of all countries and eras is:

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1. G. P. Harnwell and J. J. Livingood, *Experimental Atomic Physics*, p. ix. New York: McGraw-Hill Book Company, 1933.

Poggendorff, Johann C. *Biographisch-Literarisches Handwörterbuch zur Geschichte der Exacten Wissenschaften.* Leipzig: J. A. Barth, 1863-1904; Berlin: Verlag Chemie, 1926-1940. 6 vols. in 11.

The last volume published to date covers the period 1923 through 1931. In addition to biographical information, each biographee's important publications are listed.

Leading scientists from Archimedes to Einstein appear in:

Howard, A. V. *Chambers's Dictionary of Scientists.* New York: E. P. Dutton and Company, 1951. 499 pp.

Other comprehensive sources, such as *Lippincott's Biographical Dictionary* (Thomas) and *Biographie Universelle* (Michaud) are listed under Biography in Winchell.[2] Here one finds also the various national encyclopedias, such as the British *Dictionary of National Biography,* and the *Dictionary of American Biography,* both of which exclude living persons. On the other hand, the *National Cyclopaedia of American Biography* includes contemporaries, thus supplementing the directories mentioned in the next paragraph. The *Encyclopedia Americana* and others should not be overlooked as sources of biographical articles on famous scientists of the past.

Directories.

For present day scientists of the United States, there is a very extensive compilation of brief biographical accounts, viz:

Cattell, Jaques, editor. *American Men of Science.* (Eighth Edition.) Lancaster, Pa.: The Science Press, 1949. 2836 pp.

It lists 50,000 names. Incidentally, Visher[3] has written an interesting book on the scientists of the half-century, opposite whose names asterisks[4] have appeared as indication of their fellow scientists' esteem. Collegiate and doctoral training, birthplace, distribution, backgrounds, and developmental influences were studied in an effort to identify factors that contribute to

2. C. M. Winchell, *Guide to Reference Books,* pp. 430-451. (Seventh Edition.) Chicago: American Library Association, 1951.
3. S. S. Visher, *Scientists Starred, 1903-1943, in "American Men of Science."* Baltimore: The Johns Hopkins Press, 1947. 556 pp.
4. Last edition of *American Men of Science* to employ such asterisks was 1944 ed.

scientific achievement. Cf. Knapp and Goodrich's investigation.

Longer résumés may be found in the more general *Who's Who in America;* its British counterpart, *Who's Who;* and sometimes in *Who's Who in Engineering* if the individual is a technologist as well. *Current Biography,* an H. W. Wilson Company monthly and annual publication, provides lengthy informal sketches of scientists and others in the news. *Biographical Memoirs,* published by the National Academy of Sciences, and the Royal Society of London's *Obituary Notices of Fellows,* both present substantial biographies of recently deceased scientists, with their portraits and lists of writings. At intervals the American Physical Society, the Physical Society [London], the American Society for Engineering Education, and other groups publish identity lists of their members as special bulletins.

Nobel prize winners may be found in:

a. Schück, H., *et al. Nobel, The Man and his Prizes.* Norman, Okla.: University of Oklahoma Press, 1951. 620 pp.
On pp. 397-470, there is a narrative account of physics prize awards. A chronological table (pp. 605-607) lists Nobel Prize Winners, 1901-1949.

b. Kaplan, Flora. *Nobel Prize Winners: Charts—Indexes—Sketches.* (Second Edition.) Chicago: Nobelle Publishing Company, 1941. 144 pp.
Half-page biographical sketches accompany interesting tabular analyses (chronological, nationality, etc.).

c. MacCallum, T. W., and Taylor, Stephen. *The Nobel Prize-winners and the Nobel Foundation 1901-1937.* Zurich: The Central European Times Publishing Company, 1938. 599 pp.
Its sections are: The Nobel Foundation; Biography of prize-winners; Portraits and signatures of prize-winners.

Narrative accounts.

Unified running treatments in narrative form might possibly belong in the "Historical Approach," but the following four are more distinctly biographical in content and title:

a. Hart, Ivor B. *The Great Physicists.* (Second Edition.) London: Methuen and Company, 1934. 138 pp.
This has such chapter heads as: The physicists of classical antiquity; The dawn of experimental physics; Newtonian physics.

b. Fraser, Charles G. *Half-Hours with Great Scientists; The Story of Physics.* New York: Reinhold Publishing Corporation, 1948. 527 pp.
The "stories" of mechanics, acoustics, optics, etc., are recounted in very interesting fashion, and source material is included.

c. Hart, Ivor B. *Makers of Science; Mathematics, Physics and Astronomy.* London: Oxford University Press, 1923. 320 pp.

d. Turner, D. M. *Makers of Science; Electricity and Magnetism.* London: Oxford University Press, 1927. 184 pp.
As in the other books of this group, biographical details have been skilfully woven with the development of science.

Multiple biographies.

Good examples of compilations of longer treatments of several scientists are:

a. Crowther, J. G. *Men of Science; Humphry Davy, Michael Faraday, James Prescott Joule, William Thomson, and James Clerk Maxwell.* New York: W. W. Norton and Company, 1936. 332 pp.

b. Lenard, Philipp. *Great Men of Science; A History of Scientific Progress,* translated from the Second German Edition. London: G. Bell and Sons, 1933. 389 pp.
Depicting scientists as living people, Lenard states (p. xiii):

> My joy was great to find that these personalities so well matched the greatness of their achievements, that they were fit to serve as examples to future generations both from the point of view of their work and from that of their lives.

Some of them are: Archimedes, Galileo, Pascal, Descartes, Boyle, Huygens, Newton, Cavendish, Coulomb, Volta, Davy, Young, Ohm, Faraday, and Maxwell.

c. Bolton, Sarah K. *Famous Men of Science.* (Revised Edition.) New York: Thomas Y. Crowell Company, 1938. 376 pp.
Humanized treatments show how Galileo, Newton, Faraday, Lord Kelvin, and the Curies overcame obstacles.

d. Appleyard, Rollo. *Pioneers of Electrical Communication.* London: The Macmillan Company, 1930. 347 pp.
The ten men selected are: Maxwell, Ampère, Volta, Wheatstone, Hertz, Oersted, Ohm, Heaviside, Chappe, and Ronalds.

è. Macfarlane, Alexander. *Lectures on Ten British Physicists of the Nineteenth Century.* New York: John Wiley and Sons, 1919. 144 pp.
The physicists are: Maxwell, Rankine, Tait, Sir William Thomson, Babbage, Whewell, Stokes, Airy, Adams, and Herschel.

Individual Biography

When more extensive information on the life and achievements of a man of science than can be provided by general compendia is sought, one reads the longer single-subject accounts, assuming their availability.

Higgins has compiled exhaustive lists of full-length biographies of physicists and others, which readily indicate whether substantial life treatments have been published. These lists may be consulted in original form among the pages of the *American Journal of Physics,*[5] or more compactly in:

Higgins, Thomas J. *Biographies of Engineers and Scientists.* Chicago: Illinois Institute of Technology, 1949. 62 pp. (Its *Research Publications,* Vol. 7, No. 1.)

An earlier miscellaneous list was:

Pittsburgh. Carnegie Library. *Men of Science and Industry.* Pittsburgh: The Library, 1915. 189 pp.
This furnished a key to the biographical material on scientists, engineers, inventors, and physicians, in the library collection at the time.

A general current listing of biographical books and periodical articles, the *Biography Index,*[6] is frequently useful because it has a profession index in addition to its main alphabet of personal names. It appears quarterly, with periodic cumula-

5. T. J. Higgins, "Book-Length Biographies of Physicists and Astronomers." *American Journal of Physics,* 12: 31-39, February, 1944. Also, for addenda, *ibid,* 12: 234-236, August 1944; and 16: 180-182, March 1948.
6. Published by the H. W. Wilson Company.

tions, and should not be confused with the same publisher's *Current Biography,* previously described under Directories. The biography sections of the *Standard Catalog* series[6] (*for Public Libraries* and *for High School Libraries,* respectively) list recommended biographies, including some for science. In one's own library, such material is to be found in the card catalog under personal name and under the headings "Physics — Biography," "Science—Biography," and possibly "Scientists," "Physicists," etc. New publications may also be found in the *Cumulative Book Index.* For portraits, see the section Pictorial Devices under *Presentational Approach* in Chapter IX.

Only a few examples of individual (as opposed to multiple) biography need be cited:

a. Sullivan, John W. N. *Isaac Newton, 1642-1727.* New York: The Macmillan Company, 1938. 275 pp.

b. More, Louis T. *The Life and Works of the Honourable Robert Boyle.* London: Oxford University Press, 1944. 313 pp.

c. Milne, Edward Arthur. *Sir James Jeans; A Biography.* Cambridge, England: At the University Press, 1952. 175 pp.

d. Garbedian, Haig G. *Albert Einstein; Maker of Universes.* New York: Funk and Wagnalls Company, 1939. 328 pp.

Occasionally a scientist will venture an autobiography:

a. Millikan, Robert A. *Autobiography.* New York: Prentice-Hall, Inc., 1950. 311 pp.

b. Thomson, Sir Joseph J. *Recollections and Reflections.* New York: The Macmillan Company, 1937. 451 pp.

A personal record of different type, focused upon experimental occurrences, is an outstanding classic:

Faraday's Diary, being the Famous Philosophical Notes of Experimental Investigation made by Michael Faraday during the years 1820-1862, edited by Thomas Martin. London: G. Bell and Sons, 1932-1936. 7 vols. and index.

Sir William H. Bragg states in the foreword (p. v):

> He was in the habit of describing each experiment, in full and careful detail, on the day on which it was made. . . . The main interest of the Diary lies, however, quite outside the range of propositions and experimental proofs. It centres round the methods of Faraday's attack, both in thought and in experiment: it depends on the records of the workings of his mind as he mastered each research in turn, and on his

attitude not only to his own researches but also to scientific advance in general.

Festschrift is the German term applied to a collection of essays prepared by a scientist's friends in his honor. Examples follow:

a. *Festschrift Ludwig Boltzmann gewidmet zum Sechzigsten Geburtstage 20. Februar 1904.* Leipzig: J. A. Barth, 1904. 930 pp.

b. *Jubilé de Marcel Brillouin. Mémoires Originaux offerts à Marcel Brillouin à l'occasion de son 80e Anniversaire.* Paris: Gauthier-Villars, 1935. 441 pp.

c. *Contributions to the Mechanics of Solids dedicated to Stephen Timoshenko by his Friends on the occasion of his Sixtieth Birthday Anniversary.* New York: The Macmillan Company, 1938. 277 pp.

The first paper is a biographical sketch by John M. Lessells, with a bibliography of Timoshenko's writings.

Individual Writings

Although not biographical, of course, the collected publications of scientists are included under the Biographical Approach because of personal connotation. By their works do we not indeed know them?

Bibliographies.

Examples of bibliographies that have been compiled to chart prolific writings follow:

a. Maire, Albert. *Bibliographie Générale des Oeuvres de Pascal.* Paris: L. Giraud-Badin, 1925-1927. 5 vols.

This includes critical and biographical data.

b. Gray, George J. *A Bibliography of the Works of Sir Isaac Newton.* (Second Edition.) Cambridge, England: Bowes and Bowes, 1907. 80 pp.

Closely related is the commentary, exemplified by:

Donnan, F. G., and Haas, Arthur, editors. *A Commentary on the Scientific Writings of J. Willard Gibbs.* New Haven, Conn.: Yale University Press, 1936. 2 vols.

This treatise constitutes a memorial supplement to Gibbs' works, cited below.

Collected works.

Library collections include many collective volumes of physicists' contributions, indexed in the card catalog under the heading "Physics — Collected Works" as well as under personal names. Poggendorff (cited early in this chapter) mentions them, and there is a representative list in a textbook[7] by Millikan, *et al.*

Random selections from among numerous available sets are:

a. Fourier, Jean B. J. *Oeuvres de Fourier,* publiées par les soins de Gaston Darboux. Paris: Gauthier-Villars, 1888-1890. 2 vols.

b. Fresnel, Augustin. *Oeuvres Complètes d'Augustin Fresnel,* publiées par Henri de Senarmont, *et al.* Paris: Imprimerie Impériale, 1886-1870. 3 vols.

c. Gibbs, J. Willard. *The Collected Works of J. Willard Gibbs.* New York: Longmans, Green and Company, 1928. 2 vols.

d. Joule, James Prescott. *The Scientific Papers,* published by the Physical Society of London. London: Taylor and Francis, 1884-1887. 2 vols.

e. Lorentz, H. A. *Collected Papers.* The Hague, Netherlands: Martinus Nijhoff, 1935-1939. 9 vols.

This attractive set comprises papers in French, English, German and Dutch; introductory prefaces in English; and systematic and chronological bibliographies of the writings (Vol. 9, pp. 411-434).

f. Rayleigh, John W. S. *Scientific Papers, by John William Strutt,*[8] *3d Baron Rayleigh.* Cambridge, England: At the University Press, 1899-1920. 6 vols.

Source material.

No more fascinating approach to scientific progress through

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7. R. A. Millikan, D. Roller, and E. C. Watson, *Mechanics, Molecular Physics, Heat, and Sound.* Boston: Ginn and Company, 1937. Bibliog.: pp. 435-456.
8. Note that library card catalogs use *see references* between name variants of Lords Rayleigh, Kelvin (William Thomson), *et al.* One must distinguish between successive Lords Rayleigh also; the *4th Baron Rayleigh* is Robert John Strutt

the ages can be taken than through the original papers of the great men of science, revealing obstacles surmounted and techniques developed. As Silvanus P. Thompson asserts emphatically in his introduction to Mottelay's great bibliography:

> The art of scientific discovery—for it is an art—can be attained in but one way, the way of attainment in all arts, namely, by practising it. In the practice of art, the aspirant may at least learn something that all the textbooks cannot drill out of him, and which will help him in his practice, by the careful examination of the actual ways in which the discoveries of science, now facts of history, were actually made. But, to do this, he must throw overboard for a time the systematic textbooks, he must abandon the logical expositions which embody, at second hand, or at third hand, the antecedent discoveries, and he must go to the original sources, the writings and records of the discoverers themselves, and learn from them how they set to work. The modern compendious handbooks, in which the results of hundreds of workers have been boiled down, as it were, to a uniform consistency, is exactly the intellectual pabulum which he must eschew.

This recourse to science in its nascent state is rendered delightful as well as instructive because invariably the great experimenters are also masters of lucid scientific exposition.

The standard source book is:

Magie, William F. *A Source Book in Physics.* New York: McGraw-Hill Book Company, 1935. 620 pp.

Selected passages are given (in English throughout), together with brief biographical sketches of important physicists of the period 1600-1900. This book should always be conveniently at hand for frequent use.

Other useful ones are:

a. Cohen, Morris R., and Drabkin, I. E. *A Source Book in Greek Science.* New York: McGraw-Hill Book Company, 1948. 579 pp.

Of physics interest are excerpts from Aristotle, Euclid, Archimedes, Ptolemy, Lucretius, Hero, *et al.*

b. Dampier-Whetham, William C., and Dampier-Whetham, Margaret. *Cambridge Readings in the Literature of Science.* Cambridge, England: At the University Press, 1924. 275 pp.

The extracts are arranged to outline cosmogony, atomic theories, and evolution. Archimedes, Corpernicus, Galileo, Newton, LaPlace, Avogadro, Sir J. J. Thomson, F. W. Aston, H. G. J. Moseley, Sir Ernest Rutherford, *et al.*, are represented.

c. Knickerbocker, William S. *Classics of Modern Science (Copernicus to Pasteur).* New York: Alfred A. Knopf, 1927. 384 pp.

Good literary style is here exemplified by passages from Copernicus, Galileo, Boyle, Huygens, Newton, Franklin, Volta, Rumford, Dalton, Avogadro, Faraday, Henry, von Helmholtz, Maxwell, and other scientists.

d. Dannemann, Friedrich. *Aus der Werkstatt Grosser Forscher.* (Vierte Auflage.) Leipzig: Wilhelm Engelmann, 1922. 442 pp.

As the title indicates, extracts from the laboratories of the great investigators of all nationalities and eras are chronologically presented in German. Many are taken from *Ostwalds Klassiker,* described below.

Further readings appear in F. S. Taylor's *Short History of Science,* and F. H. Law's *Science in Literature.*

Source material series have been issued by several publishers. Component volumes may be traced from series cards in library catalogs, from publishers' lists, or from flyleaves of individual books.

1. English language presentations may be found in:

a. *Harper's Scientific Memoirs,* edited by Joseph S. Ames. New York: American Book Company; Harper and Brothers, 1898-1902. 15 vols.

Representative titles follow:

Barker, George F. *Röntgen Rays; Memoirs by Röntgen, Stokes, and J. J. Thomson.* 1899. 76 pp.

Crew, Henry. *The Wave Theory of Light; Memoirs by Huygens, Young, and Fresnel.* 1900. 164 pp.

Mackenzie, A. Stanley. *The Laws of Gravitation; Memoirs by Newton, Bouguer, and Cavendish.* 1900. 160 pp.

Magie, William F. *The Second Law of Thermodynamics; Memoirs by Carnot, Clausius, and Thomson.* 1899. 151 pp.

A review of this fifteen-volume series is available.[9]

b. *Bell's Classics of Scientific Method.* London: G. Bell and Sons, 1922-

Typical units in this current series, designed to provide the lay-

9. *Physical Review,* 15: 192, September 1902

man with reproductions of the great masterpieces, and to trace the scientific thought and action leading up to them, are the following:

Roberts, Michael, and Thomas, E. R. *Newton and the Origin of Colours.* 1934. 133 pp.

Wood, Alexander. *Joule and the Study of Energy.* 1925. 88 pp.

2. German language presentations are given in:

Ostwalds Klassiker der Exakten Wissenschaften, begründet von Wilhelm Ostwald; herausgegeben von Wolfgang Ostwald. Leipzig: Akademische Verlagsgesellschaft, 1889-

The publisher issued a twenty-eight page classified list and author index for this most extensive series as of 1937, comprising 243 books at the time. In the section "Physik" of this pamphlet, pp. 10-18, there are 88 entries. Selected work of German scientists is furnished in the original German text, while English and French contributions have undergone translation. One may use the volumes pertaining to Faraday, Newton, *et al.,* for general or comparative purposes, after recovery from initial surprise at their German rendering. Because of the series' comprehensiveness, any famous man of science sought is likely to be included. Only No. 244 of the series, published just after the index pamphlet was issued, need be cited as an example:

Ohm, Georg S., and Fechner, Gustav T. *Das Grundgesetz des Elektrischen Stromes,* herausg. C. Piel. 1938. 45 pp.

3. French language presentations appear in *Les Maîtres de la Pensée Scientifique,* a lesser series published in Paris by Gauthier-Villars.

See also Brunet's *Histoire des Sciences.*

Summary

Familiarity with the struggles and achievements of men of science endows them with vitality and substance, qualities sorely lacking when merely names are learned in connection with important laws or discoveries. Multiple lives merge into historical accounts. Biographical sources, both current and retrospective, have been mentioned, notably Higgins' extensive lists. From individual writings, embodied in collected works or read

conveniently in source book form, comes a feeling of participation in the hard original search for new physical data and concepts.

CHAPTER V

EXPERIMENTAL APPROACH
Experimentation, Equipment, and Techniques

Experimentation characterizes the work of the physicist. His laboratory and its procedures, which underlie broader research contributions, are the subject of this chapter.

Overview

When Galileo demonstrated by actual test (probably *not* publicly from the Tower of Pisa[1]) that bodies fall with the same acceleration regardless of mass, he was acting in accordance with the scientific method. Stewart has prepared an extremely concise summary[2] of the scientific method, which is also exemplified in the *Harvard Case Studies in Experimental Science,*[3] edited by J. B. Conant. See also:

a. Barry, Frederick. *The Scientific Habit of Thought.* New York: Columbia University Press, 1927. 358 pp.

b. Dingler, Hugo A. *Die Methode der Physik.* München: Ernst Reinhardt, 1938. 422 pp.

c. Wolf, Abraham. *Essentials of Scientific Method.* London: George Allen and Unwin, Ltd., 1925. 160 pp.

Owen warns that the college laboratory does not automatically nurture scientific thinking habits:

> But how well does the ordinary laboratory experience contribute to the development of skill in applying the scientific method and of desirable attitudes and habits that should go with it? Consider that in the usual experiment someone else states the problem, develops the

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1. Cf. L. Cooper, *Aristotle, Galileo, and the Tower of Pisa.* Ithaca, N. Y.: Cornell University Press, 1935. 102 pp.; and its review by L. W. Taylor in *American Physics Teacher,* 4: 44-45, February 1936.
2. O. M. Stewart, and N. S. Gingrich, *Physics,* pp. 700-704. (Fifth Edition.) Boston: Ginn and Company, 1950.
3. See J. W. Shirley, "The Harvard Case Studies...: The Evolution of an Idea." *American Journal of Physics,* 19: 419-423, October 1951.

theory showing how general principles apply, outlines how the information is to be obtained and how it is to be interpreted and, in many cases, determines what the conclusions must be. Originality, open-mindedness, even intellectual honesty are not encouraged. The student is expected to follow the reasoning outlined for him and thereby learn something about the scientific method. The assumption must be that he cannot do this for himself. If so, the experiment does not help him much in learning to apply the method to his own problems.[4]

Experimental physics possesses an encyclopedic *Handbuch der Experimental Physik* of monumental proportions.

Physical Laboratory

Design.

The planning of laboratories for maximum efficiency is detailed in:

Coleman, H. S., editor. *Laboratory Design: National Research Council Report on Design, Construction and Equipment of Laboratories.*[5] New York: Reinhold Publishing Corporation, 1951. 393 pp.

This includes a thorough discussion of materials and equipment for teaching and industrial laboratories. Part IV presents short illustrated descriptions of various laboratories.

Further descriptions useful for comparative purposes are found in brochures occasionally emanating from various institutions, such as:

a. *A History of the Cavendish Laboratory, 1871-1910.* London: Longmans, Green and Company, 1910. 342 pp.

This interesting account, prepared by the associates of Sir J. J. Thomson, depicts the layout, history and guiding philosophy of this famous laboratory[6] at Cambridge University, England.

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4. G. E. Owen, "Some Contributions the Physics Laboratory can make to General Education." *American Journal of Physics*, 17: 270-272, May 1949.
5. See also *Laboratory Design for Handling Radioactive Materials*, a 140-page discussion of layout, shielding, ventilation, etc., comprising the *Proceedings of the Third Research Correlation Conference*; available from N. R. C. Building Research Advisory Board in 1952.
6. See also: Alexander Wood, *The Cavendish Laboratory.* Cambridge, England: At the University Press, 1946. 58 pp.; and W. L. Bragg, "A Center of Fundamental Research." *Physics Today*, 6 (No. 1): 18-19, January 1953.

b. *The Physical Laboratories of the University of Manchester; A Record of 25 Years' Work.* Manchester, England: At the University Press, 1906. 142 pp.
Another early laboratory is described with four plans.

c. *The Physical Laboratories of Harvard University.* Cambridge, Mass.: Harvard University Press, 1932. 47 pp.

d. Langdon-Davies, John. *Jubilee Book of the National Physical Laboratory.* London: H. M. Stationery Office, 1951. 103 pp.

Instruments.

Interesting accounts of old instruments associated with research and teaching at Oxford and Cambridge Universities, respectively, appear in:

a. Gunther, Robert T. *Early Science in Oxford,* Vol I, Pt. iii, pp. 189-324. London: Oxford University Press, 1923.

b. Gunther, Robert T. *Early Science in Cambridge.* London: Oxford University Press, 1937. 513 pp.

Harvard University's collection of early scientific instruments for the study of natural philosophy is featured in:

Cohen, I. Bernard. *Some Early Tools of American Science.* Cambridge, Mass.: Harvard University Press, 1950. 201 pp.

Wolf's historical treatises also have sections on early scientific instruments.

The following compendia of modern instruments may be useful to the physicist although considerable space is devoted to those beyond his special interests:

a. Cooper, Herbert J. *Scientific Instruments,* I-II. Brooklyn, N. Y.: Chemical Publishing Company, 1946-1949. 2 vols.

b. Brown, Earle B. *Optical Instruments.* Brooklyn, N. Y.: Chemical Publishing Company, 1945. 567 pp.

c. Martin, Louis C. *Optical Measuring Instruments.* London: Blackie and Son, 1924. 270 pp.
(See also his more recent *Technical Optics.*)

d. Greenwood, Ivan A., *et al. Electronic Instruments.* New York: McGraw-Hill Book Company, 1948. 708 pp. (M. I. T. Radiation Laboratory Series Vol. 21.)

The general design and construction of instruments is treated in:

a. Elliott, A., and Dickson, J. H. *Laboratory Instruments; Their Design and Application.* London: Chapman and Hall, Ltd., 1951. 414 pp.

Some of the chapters are: The accuracy attainable in machining operations; Casting and jointing of metals; Constrained motion and constraints; Magnification of small displacements; Sensitivity and errors of instruments; Damping; Tests for straightness, flatness and squareness; Optical instruments.

b. Whitehead, T. N. *The Design and Use of Instruments and Accurate Mechanism.* New York: The Macmillan Company, 1934. 283 pp.

"This book is concerned with that type of mechanism whose function is directly dependent on the accuracy with which the component parts achieve their required relationships."

c. Draper, Charles S., *et al. Instrument Engineering.* Vol. I. New York: McGraw-Hill Book Company, 1952. 285 pp. (McGraw-Hill Pubs. in Aero. Science.)

First-hand acquaintance with current instrument output may be derived from annual exhibitions, either by personal attendance or through their descriptive materials. In the United States, two important annual exhibits are staged in conjunction with the Instrument Society of America Convention and the National Electronics Conference. Scientific instrument and apparatus makers[7] often conduct displays at meetings of societies associated with the American Institute of Physics. In England, there are annual exhibitions which put forth elaborate descriptive brochures under the auspices of the Physical Society. The Proceedings of the 1950 London Conference on Optical Instruments are now available.[8]

Useful trade literature includes instrument catalogs,[9] house organs, manuals, and more extensive publications like:

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7. See Scientific Apparatus Makers Association, *Membership List.* Chicago: The Association, 1951. 25 pp.
8. Published in New York by John Wiley and Sons, 1952. 264 pp.
9. For example, those issued by the Central Scientific Company, W. M. Welch Scientific Company, Leeds and Northrup Company, Gaertner Scientific Corporation, James G. Biddle Company, etc., etc.

British Optical Instruments Manufacturers' Association. *Dictionary of British Scientific Instruments.* London: Constable and Company, 1921. 335 pp.

Relevant periodicals include the *Review of Scientific Instruments;* its British counterpart, the *Journal of Scientific Instruments; Journal of Applied Physics; Electronics; Instruments;* etc. (The last two publish annual directories.)

Laboratory Procedures

Effective methods of experimental attack and manipulation, that have been evolved over long periods through trial and error, are passed along in the form of procedure manuals. These aid the practicing scientist engaging in work outside his specialty, but are usually oriented towards the physics student in regular courses.

Basic techniques.

Mastery of basic laboratory operations is essential before undertaking advanced experimental research. The following books are helpful:

a. Strong, John, *et al. Procedures in Experimental Physics.* New York: Prentice-Hall, Inc., 1938. 642 pp.

Copiously illustrated, this compendium provides an extremely wide range of data for the practicing physicist, e.g.: Fundamental operations in laboratory glass blowing; Laboratory optical work; Technique of high vacuum; Coating of surfaces; Electrometers and electroscopes; Geiger counters: Vacuum thermopiles and the measurement of radiant energy; Photoelectric cells and amplifiers; Molding and casting.

b. Kohlrausch, F. *Praktische Physik, zum gebrauch für Unterricht, Forschung und Technik.* (18. Auflage.) Leipzig: B. G. Teubner, 1943. 2 vols.: 542, 584 pp. (Photo-reprint, New York: Mary S. Rosenberg, 1947.)

This is an important collection of instrumental measurements and techniques, for research worker and student. It is the work of numerous editors, and has copious bibliographical references throughout.

c. Ansley, A. J. *An Introduction to Laboratory Technique.*

(Second Edition.) London: The Macmillan Company, 1950. 288 pp.
The laboratory assistant in educational institutions will find this useful for suggestions on maintaining and constructing apparatus. It treats electrical measuring, electroplating, glass-working, graduation of apparatus, soldering, etc.

d. Lang, Ruth, compiler. *Laboratory and Workshop Notes; Further Laboratory and Workshop Notes.* London: Edward Arnold and Company, 1949-1951. 272; 290 pp.
These are useful selections from the *Journal of Scientific Instruments.*

For glass, a constantly used medium, there are:

a. Barr, W. E., and Anhorn, V. J. *Scientific and Industrial Glass Blowing and Laboratory Techniques.* Pittsburgh: Instruments Publishing Company, 1949. 388 pp.

b. Heldman, Julius D. *Techniques of Glass Manipulation in Scientific Research.* New York: Prentice-Hall, Inc., 1946. 132 pp.

c. Dévé, Charles. *Optical Workshop Principles.* London: Adam Hilger, Ltd., 1943. 306 pp.

d. Twyman, Frank. *Prism and Lens Making.* (Second Edition.) London: Hilger and Watts, Ltd., 1952. 629 pp.

General manuals.

As will be indicated under Educational Approach (Chapter VII), modern educational trends are away from rote-learning towards purposeful action. Accordingly, students should be encouraged to think during the course of an experimental study, rather than follow the manual blindly as a routine task. Laboratory guides[10] for college use are as numerous as the various textbooks of physics. The contents and arrangement of each reflect the author's preferences as to sequence, inclusion and style. Johnson states:

> In the manuals now in use in school laboratories over the country the forms of presentation of subject matter reach two extremes. Some of these works—offered for standard college use—afford little more

10. See W. V. Norris, "A Study in Laboratory Manuals." *American Physics Teacher,* 6: 135-138, June 1938.

than child's play. Others—not infrequently the productions of men eminent for research—are so exacting, so mathematical, or so detailed, that they require uncommon preparation, and often a special equipment. They may be serviceable in the laboratories of the technical schools in which they were written, but they hardly seem suitable for general use.[11]

Only a few of the more adaptable general laboratory manuals[12] need be cited:

a. Ingersoll, Leonard R., and Martin, Miles J. *A Laboratory Manual of Experiments in Physics.* (Fifth Edition.) New York: McGraw-Hill Book Company, 1942. 342 pp.

b. Schulz, William F. *Manual of Experiments in General Physics.* New York: D. Van Nostrand Company, 1932. 353 pp.

c. White, Marsh W. *Experimental College Physics.* (Second Edition.) New York: McGraw-Hill Book Company, 1940. 383 pp.

The purposes of laboratory work are aptly summarized (p ix):

(1) to fix more clearly in mind the great facts and principles of Nature being studied in the classroom, (2) to develop the student's thinking and reasoning powers, (3) to furnish an opportunity for a first-hand study and confirmation of some of the fundamental laws of the science, and (4) to acquaint the student with some of the methods, instruments and techniques of physical measurements, thus enabling him more adequately to obtain an appreciation of the possibilities and limitations of the scientific spirit and method of investigation.

d. Miller, Dayton C. *Laboratory Physics.* (New Edition.) Boston: Ginn and Company, 1932. 438 pp.

e. Schneider, Walter A., and Ham, Lloyd B. *Experimental Physics for Colleges.* (Revised Edition.) New York: The Macmillan Company, 1949. 442 pp.

f. Jerrard, H. G., and McNeill, D. B. *An Introduction to Experimental Physics.* London: George G. Harrap and Company, 1951. 576 pp.

General laboratory manuals of more advanced type are represented by the following group:

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11. E. H. Johnson, *Laboratory Physics*, p. iii. New York: Harcourt, Brace and Company, 1923.
12. See also a series of 145 separate *Selective Experiments in Physics*, edited by V. E. Eaton, *et al.*, issued by the Central Scientific Company, 1940-1944.

a. Searle, George F. C. *Experimental Physics.* Cambridge, England: At the University Press, 1934. 363 pp.
Copious mathematical treatments accompany the experiments, designed for students at the famous Cavendish Laboratory.

b. Calthrop, J. E. *Advanced Experiments in Practical Physics.* London: William Heinemann, 1938. 121 pp.
Included are interesting advanced experiments of classical and modern physics, performed with standard equipment in most instances.

c. Worsnop, Bernard L., and Flint, Henry T. *Advanced Practical Physics for Students.* (Ninth Edition.) London: Methuen and Company, 1951. 754 pp.
This compendium is of unusually large proportions, and presents theoretical summaries and alternative procedures.

See also the demonstration experiment compendia listed in the section Lectures under Presentational Approach in Chapter IX.

Special manuals.

Laboratory manuals and technique résumés for special fields of physics are helpful to those wishing to go beyond the general laboratory course. These may be supplemented by the general manuals, and by experiment sections found in certain books, e.g., W. C. Michels' *Advanced Electrical Measurements;* R. L. Weber's *Heat and Temperature Measurement;* and F. R. Watson's *Sound.*

Aerodynamics

a. Pavian, Henry C. *Experimental Aerodynamics.* New York: Pitman Publishing Corporation, 1940. 168 pp.
Simple wind-tunnel experiments are performed.

b. Pankhurst, R. C., and Holder, D. W. *Wind-Tunnel Technique.* London: Sir Isaac Pitman and Sons, 1952. 702 pp.
This is intended for graduates entering the field of experimental aerodynamics. Some chapter headings are: Wind-tunnel design; Measurement of fluid velocity; Wind-tunnel balances; Manometers; Notes on models and rigging.

See also Fluid mechanics in index.

Atoms; Radiation

a. Harnwell, Gaylord P., and Livingood, J. J. *Experimental*

Atomic Physics. New York: McGraw-Hill Book Company, 1933. 472 pp.
The experiments deal with light pressure, black body radiation, electron diffraction, Raman effect, etc.

b. Bleuler, Ernst, and Goldsmith, G. J. *Experimental Nucleonics.* New York: Rinehart and Company, 1952. 393 pp.
The introduction (on radiation protection, laboratory equipment, and preparation of sources) is followed by twenty-four experiments, e.g., Technique of measurements with Geiger-Müller counters; Absorption of gamma rays; Separation of nuclear isomers; Range and energy loss of alpha particles; Cosmic rays.

c. Segrè, Emilio. *Experimental Nuclear Physics.* New York: John Wiley and Sons, 1953. Vols. 1-2.
This comprehensive survey of techniques will comprise three volumes.

For wartime-evolved techniques, see:

Graves, Alvin C., and Froman, D. K. *Miscellaneous Physical and Chemical Techniques of the Los Alamos Project.* New York: McGraw-Hill Book Company, 1952. 323 pp.

There is an interesting article on the Oak Ridge laboratory course:

Klema, E. D.; Stephenson, R. J.; and Taylor, Snowden. "Experimental Reactor Physics Course at the Oak Ridge School of Reactor Technology." *American Journal of Physics,* 21: 300-304, April 1953.
The laboratory manual of the course is available from the Office of Technical Services, Department of Commerce, Washington 25, D. C., priced at $1.05, and designated AECU-2164.

See also index under Radiation and Atomic Energy.

Elasticity

Searle, George F. C. *Experimental Elasticity.* (Second Edition.) Cambridge, England: At the University Press, 1933. 189 pp.

See also Viscosity, and Properties (mechanical).

Electricity; Magnetism

a. Terry, Earle M., and Wahlin, Hugo B. *Advanced Laboratory Practice in Electricity and Magnetism.* (Third Edition.) New York: McGraw-Hill Book Company, 1936. 318 pp.

b. Loeb, Leonard B. *A Laboratory Manual of Electricity and Magnetism.* (Revised Edition.) Stanford University, Cal.: Stanford University Press, 1941. 121 pp. plus 113 data forms.

c. Gregg, Robert Q.; Hammond, H. E.; and Frost, R. H. *A Manual of Electrical Measurements.* Cambridge, Mass.: Addison-Wesley Press, 1950. 150 pp.

This is a book of experiments grouped under section headings such as: Galvanometer; Resistance and capacitance measurements; Magnetic measurements; Vacuum tubes, etc.

See also index under Electricity.

Electronics

a. Müller, Ralph H.; Garman, R. L.; and Droz, M. E. *Experimental Electronics.* New York: Prentice-Hall, Inc., 1942. 330 pp.

In conjunction with characteristics and non-communication applications of electron tubes, seventy experiments are described in detail.

b. Schulz, E. H., and Anderson, L. T. *Experiments in Electronics and Communication Engineering.* New York: Harper and Brothers, 1943. 381 pp.

Over a hundred experiments are presented, covering basic circuits, electronics, and radio.

c. Higgy, Robert C. *Fundamental Radio Experiments.* New York: John Wiley and Sons, 1943. 95 pp.

Two compendia of techniques rather than experiments are:

a. Bachman, C. H. *Techniques in Experimental Electronics.* New York: John Wiley and Sons, 1948. 252 pp.

Equipment and procedures for maintaining beams of charged particles in a vacuum are discussed, under chapter headings such as: Pumps; Vacuum gauges; Controls and gadgets; Leak detection; Assembling and processing of electronic devices.

b. Elmore, William C., and Sands, Matthew. *Electronics; Experimental Techniques.* New York: McGraw-Hill Book Company, 1949. 417 pp.

The electronic instrumentation work that had been done at Los Alamos Laboratory during the development of the atomic bomb

is described, under such headings as: Circuit components; Voltage amplifiers; Electronic counters; and Oscillographs.

See also index under Electronics.

Harmonic motion

Searle, George F. C. *Experimental Harmonic Motion.* Cambridge, England: At the University Press, 1922. 100 pp.

Physics teachers will agree with Searle when he states (p. 5):

> The subject of Harmonic Motion presents difficulties to many students. For some reason they fail to get any real grasp of the principles and in consequence dare not trust themselves to apply them to the simple examples they meet with in practical physics, even in those cases where the mathematical analysis is quite elementary. The present little volume is an attempt to meet the difficulty.

Optics

a. Taylor, Lloyd W. *College Manual of Optics.* Boston: Ginn and Company, 1924. 236 pp.

Classroom textbook and laboratory manual are combined rather than being artificially separated.

b. Wagner, Albert F. *Experimental Optics.* New York: John Wiley and Sons, 1929. 203 pp.

Some of the divisions are: Index of refraction and spectrometry; Lens aberrations; Photometry; Telescopic instruments; Measurement of constants of microscopes.

c. Searle, George F. C. *Experimental Optics.* Cambridge, England: At the University Press, 1925. 357 pp.

See also index under Optics and Light.

Spectroscopy

a. Sawyer, Ralph A. *Experimental Spectroscopy.* (Second Edition.) New York: Prentice-Hall, Inc., 1951. 358 pp.

This is a survey of techniques rather than an experiment manual. It is designed to acquaint students and research workers with spectrographs and their use. There is an excellent descriptive list of spectroscopic charts and tables on pp. 221-229.

b. Harrison, George R.; Lord R. C.; and Loofbourow, J. R. *Practical Spectroscopy.* New York: Prentice-Hall, Inc., 1948. 605 pp.

c. Tolansky, Samuel. *High Resolution Spectroscopy.* London: Methuen and Company, 1947. 291 pp.

See also index under Spectroscopy.

General measurements.

The importance of measurement in physical science is emphasized by Lord Kelvin:

> I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is a meagre and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of *science*, whatever the matter may be.[13]

An overall study of the principles of measurement is provided by:

Campbell, Norman R. *An Account of the Principles of Measurement and Calculation.* London: Longmans, Green and Company, 1928. 293 pp.

Two less abstract manuals on precision calculations, graphical representation, etc., are:

a. Goodwin, H. M. *Elements of the Precision of Measurements and Graphical Methods.* (Second Edition.) New York: McGraw-Hill Book Company, 1920. 116 pp.

b. Worthing, Archie G., and Geffner, Joseph. *Treatment of Experimental Data.* New York: John Wiley and Sons, 1943. 342 pp.

Dimensional theory concerns the analysis of all mechanical quantities in terms of the fundamental entities, length, mass and time, irrespective of units employed. Helpful discussions include:

a. Lanchester, Frederick W. *The Theory of Dimensions and its Applications for Engineers.* London: Crosby Lockwood and Son, 1936. 314 pp.

Written in most readable style, it has strong words on the controversial[14] "slug" and a good comparison of mass vs. weight.

b. Bridgman, Percy W. *Dimensional Analysis.* (Revised Edition.) New Haven, Conn.: Yale University Press, 1931. 113 pp.

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13. W. T. Kelvin, *Popular Lectures and Addresses by Sir William Thomson*, Vol. 1, pp. 73-74. London: The Macmillan Company, 1889.
14. See also: L. A. Hawkins and S. A. Moss, "Alice and the Sluggers." *American Journal of Physics*, 13: 409-411, December 1945; and S. L. Gerhard, "Slugging Out a Case for the Pounders." *American Journal of Physics*, 18: 302-305, May 1950.

Misconceptions in methodology are cleared up.

Typical laboratory manuals on physical measurements may here be cited, although they closely resemble the general experiment compendia.

a. Zeleny, Anthony, and Erikson, Henry A. *A Manual of Physical Measurements.* (Sixth Edition.) New York: McGraw-Hill Book Company, 1937. 273 pp.

b. Ferry, Ervin S. *A Handbook on Physical Measurements.* (Second Edition of Vol. 1; Third Edition of Vol. 2.) New York: John Wiley and Sons, 1926-1929. 2 vols.

Weights and measures[15] of two systems are compared in:

a. National Industrial Conference Board. *The Metric Versus the English System of Weights and Measures.* New York: The Century Company, 1921. 261 pp. (Its Research Report No. 42.)

See especially pp. 55-65 concerning use in science and engineering.

b. *Units of Weight and Measure (United States Customary and Metric); Definitions and Tables of Equivalents.* Washington, D. C.: Government Printing Office, 1936. 68 pp. (U. S. National Bureau of Standards Miscellaneous Publication No. M121.)

English units are favored in:

Ingalls, Walter R. *Units of Weights and Measures.* New York: American Institute of Weights and Measures, 1946. 49 pp.

The metric system is strongly advocated by:

National Council of Teachers of Mathematics. *The Metric System of Weights and Measures.* New York: Bureau of Publications, Teachers College, Columbia University, 1948. 303 pp. (Its *Twentieth Yearbook,* compiled by the Committee on the Metric System.)

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15. *See also*: W. S. Bussey and M. W. Jensen, *The Index to the Reports of the National Conference on Weights and Measures, from the 1st to the 36th, 1905-1951.* Washington, D. C.: Government Printing Office, 1952. 45 pp. (U. S. National Bureau of Standards Miscellaneous Publication No. 203.) For archeological and historical evidence concerning weights and measures, see A. E. Berriman, *Historical Metrology.* London: J. M. Dent and Sons, 1953. 224 pp.

Physicists have always made general use of metric units in their cgs system, based on fundamental units of the centimeter, gram, and second, and reviewed in:

Everett, Joseph D. *Illustrations of the C. G. S. System of Units.* (Fifth Edition.) London: The Macmillan Company, 1902. 283 pp.

For electricity and magnetism, the mks system was adopted by the International Electrotechnical Commission at Brussels in 1935, to take effect five years later. This application of meter-kilogram-second units (instead of the former arbitrary "international" units) is described in:

a. Jauncey, G. E. M., and Langsdorf, A. S. *M. K. S. Units and Dimensions.* New York: The Macmillan Company, 1940. 62 pp.

b. Sas, R. K., and Pidduck, F. B. *The Metric-Kilogram-Second System of Electrical Units.* London: Methuen and Company, 1947. 60 pp.

c. "What is the Meter-Kilogram-Second System of Units?" (A Report of the American Association of Physics Teachers Committee on Electric and Magnetic Units.) *American Physics Teacher,* 6: 144-151, June 1938.

d. Moon, Parry, and Spencer, Domina E. "Utilizing the Mks System." *American Journal of Physics,* 16: 25-38, January 1948.

> The mks system gives a single comprehensive and international set of units for all of physics and engineering. . . . It has been employed extensively in recent textbooks, but authors seem to feel the lack of a general treatment of the mks system and a dearth of data expressed in mks units. The present paper attempts to remedy this difficulty by outlining the use of mks units in physics, and by giving tables of constants and conversion factors.

Standards may designate physical entities,[16] such as the pound-mass of a certain platinum block preserved in London, or a

16. For example, see these résumés of the work of our National Bureau of Standards: L. B. Macurdy, "Standards of Mass." *Physics Today,* 4 (No. 4): 7-11, April 1951; and R. E. Wilson, "Standards of Temperature." *Physics Today,* 6 (No. 1): 10-15, January 1953; also the Bureau's publications. British practice is reflected in: *Recent Developments and Techniques in the Maintenance of Standards.* London: H. M. Stationery Office, 1952. 100 pp.

standard yard marked off on a bar, but also may refer to codified procedures, definitions, specifications, etc., adopted for purposes of uniformity and mutual understanding. Extensive series of standards representing American and English practice in many fields have been published by the American Standards Association and the British Standards Institution, with annual index lists. While mostly directed towards engineers, some titles impinge upon physics, such as:

American Standard Definitions of Electrical Terms, approved by the American Standards Association, August 12, 1941. (ASA - C42 - 1941.) New York: American Institute of Electrical Engineers, 1942. 311 pp.

Electrical engineering is stressed, but there many topics of physics interest, e.g., general electrical terms, photometric quantities, radiation, electronics, and radiology. (ASA numbers, like that cited in this title, identify particular standards by subject and year.)

Other relevant standards include: acoustical, colorimetric and photometric terminologies and measurement manuals; abbreviations of scientific and engineering terms; and symbols for entities in electricity, electronics, heat, mechanics, meterology, photometry and physics. A price list and index of *American Standards* annually accompanies an issue of the ASA journal, *Standardization.* The Association issues descriptive material on the purposes and development of standards.

See also the multi-volume *Standards* and other publications of the American Society for Testing Materials.

Special measurements.

There are numerous books that discuss measurement techniques in phases of physics experimentation, such as:

Air flow

Ower, E. *The Measurement of Air Flow.* (Third Edition.) London: Chapman and Hall, Ltd., 1949. 293 pp.

This is based on work at the National Physical Laboratory.

See also Aerodynamics and Fluid Mechanics.

Color

a. *Handbook of Colorimetry,* prepared by the staff of the

Color Measurement Laboratory, Massachusetts Institute of Technology, under the direction of Arthur C. Hardy. Cambridge, Mass.: The Technology Press, 1936. 87 pp.

The authors state (p. v.):

> Despite the age and extent of man's interest in color, colorimetry is a relatively new and unfamiliar science. Until physical instruments were developed which measure color in terms of quantities and wavelengths of light, the only available methods of color specification had of necessity to be based on samples of the various colors. The fact that these samples are subject to change with time, even under the best of conditions, has made it impossible to accumulate an extensive and accurate body of knowledge concerning the diverse phenomena of color and color vision.

b. Wright, William D. *The Measurement of Colour.* London: Adam Hilger, Ltd., 1944. 223 pp.

c. Bouma, Pieter J. *Physical Aspects of Colour.* New York: Elsevier Book Company, 1948. 312 pp.

See also U. S. National Bureau of Standards Circular No. 478, G. P. O., 1950; and the index entries under Color.

Electricity; Electronics

a. Smith, Arthur W. *Electrical Measurements in Theory and Application.* (Fourth Edition.) New York: McGraw-Hill Book Company, 1948. 371 pp.

This is a standard textbook for students who have had the first-year physics course.

b. Michels, Walter C. *Advanced Electrical Measurements.* (Second Edition.) New York: D. Van Nostrand Company, 1941. 347 pp.

Superseding Smythe and Michels' earlier edition, this includes sixty experiments.

c. Harris, Forest K. *Electrical Measurements.* New York: John Wiley and Sons, 1952. 784 pp.

d. Stout, Melville B. *Basic Electrical Measurements.* New York: Prentice-Hall, Inc., 1950. 504 pp.

e. Hund, August. *High-Frequency Measurements.* (Second Edition.) New York: McGraw-Hill Book Company, 1951. 676 pp.

f. Laws, Frank A. *Electrical Measurements.* (Second Edition.) New York: McGraw-Hill Book Company, 1938. 739 pp.

g. Terman, Frederick E., and Pettit, J. M. *Electronic Meas-*

urements. (Second Edition.) New York: McGraw-Hill Book Company, 1952. 707 pp.

See also index under Electricity and Electronics.

Light.

Walsh, John W. T. *Photometry.* (Second Edition.) London: Constable and Company, 1953. 544 pp.

This is an extremely interesting and comprehensive presentation, with copious bibliographical references to all publications 1925-1949 and selected earlier ones. For a complete bibliography of photometry to 1925 consult the first edition, 1926. Some of the chapters are: Radiation; The eye and vision; Photoelectric cells; Standards and sub-standards; Light, distribution and total flux measurement; Colorimetry; Spectrophotometry; The photometric laboratory.

Barrows' *Light, Photometry and Illuminating Engineering* is also useful.

Inclusion of more modern material on photometry in textbooks is urged by Moon and Spencer in their "Photometrics in General Physics" (*American Journal of Physics,* 11: 200-208, August 1943).

See also index under Light, Color and Optics.

Radiation; Radioactivity

a. Forsythe, W. E., editor. *Measurement of Radiant Energy.* New York: McGraw-Hill Book Company, 1937. 452 pp.

This interesting survey was prepared under the auspices of the National Research Council.

b. Curtiss, Leon F. *Measurements of Radioactivity.* Washington, D. C.: Government Printing Office, 1949. 84 pp. (U. S. National Bureau of Standards Circular No. 476.)

c. Yagoda, Herman. *Radioactive Measurements with Nuclear Emulsions.* New York: John Wiley and Sons, 1949. 356 pp.

Useful books on counters include:

a. Rossi, Bruno B., and Staub, H. H. *Ionization Chambers and Counters.* New York: McGraw-Hill Book Company, 1949. 243 pp.

b. Curran, S. C., and Craggs, J. D. *Counting Tubes; Theory and Application.* New York: Academic Press, 1949. 238 pp.

c. Wilkinson, D. H. *Ionization Chambers and Counters.*

Cambridge, England: At the University Press, 1950. 324 pp.

d. Korff, Serge A. *Electron and Nuclear Counters.* New York: D. Van Nostrand Company, 1946. 212 pp.

See also index under Radiation and Radioactivity.

Sound

Beranek, Leo L. *Acoustic Measurements.* New York: John Wiley and Sons, 1949. 914 pp.

A useful section on terminology is included, pp. 15-36.

See also Chapter X—Sound.

Temperature; Heat

A monumental compendium on all aspects of temperature has been produced by the American Institute of Physics in cooperation with the U. S. National Bureau of Standards, the National Research Council, and many other organizations:

American Institute of Physics. *Temperature; Its Measurement and Control in Science and Industry.* New York: Reinhold Publishing Corporation, 1941. 1362 pp.

It is comprised of papers presented at a symposium in 1939, supplemented by useful data tables, a glossary (pp. 1327-1330), illustrations, etc. Chapters include: Temperature and temperature scales; Precision thermometry; Optical and radiation pyrometry; Thermometric metals and alloys.

Among shorter surveys are:

a. Weber, Robert L. *Heat and Temperature Measurement.* New York: Prentice-Hall, Inc., 1950. 422 pp.

This attractively designed book presents fundamental theory and a group of twenty-nine laboratory experiments, such as: Coefficient of expansion of a liquid; Radiation constant; Ratio of specific heats of air.

b. Griffiths, Ezer. *Methods of Measuring Temperature.* (Third Edition.) London: C. Griffin, 1947. 223 pp.

c. Swietoslawski, Wojciech. *Microcalorimetry.* New York: Reinhold Publishing Corporation, 1946. 199 pp.

d. White, Walter P. *The Modern Calorimeter.* New York: The Chemical Catalog Company, 1928. 194 pp.

For extremes of temperature, see Temperature (high and low) in the index.

Time

a. Bolton, L. *Time Measurement.* New York: D. Van Nostrand Company, 1924. 166 pp.
This is a popular exposition of time units and timepieces.

b. Chance, Britton, *et al. Electronic Time Measurements.* New York: McGraw-Hill Book Company, 1949. 528 pp. (M. I. T. Radiation Laboratory Series Vol. 20.)
Although a product of radar research, this has broader usefulness.

Viscosity

Barr, Guy. *A Monograph on Viscometry.* London: Oxford University Press, 1931. 318 pp.
Methods and apparatus are described in detail.

See also Elasticity, and Properties (mechanical).

Experimental Research

Research programs conducted at research institutes, universities, industrial laboratories and elsewhere fulfill the dual purpose of expanding the frontiers of scientific knowledge, and of making possible the production of all the devices of contemporary civilization.

General.

Overall discussions of pure and applied research are provided by:

a. Wilson, E. Bright. *An Introduction to Scientific Research.* New York: McGraw-Hill Book Company, 1952. 375 pp.

b. Bush, George P., and Hattery, Lowell H. *Scientific Research: Its Administration and Organization.* Washington, D. C.: American University Press, 1950. 190 pp.

c. Boyd, T. A. *Research; The Pathfinder of Science and Industry.* New York: D. Appleton-Century Company, 1935. 319 pp.

d. Industrial Research Institute. *Research in Industry; Its Organization and Management,* edited by Clifford C. Furnas. New York: D. Van Nostrand Company, 1948. 574 pp.

Other books on various phases of research are listed in the following series, which furnishes excerpts from book reviews:

Buros, Oscar K., editor. *Research and Statistical Methodology; Books and Reviews 1933-1938.* New Brunswick, N. J.:

Rutgers University Press, 1938. 100 pp.; *The Second Yearbook of Research and Statistical Methodology.* Highland Park, N. J.: The Gryphon Press, 1941. 383 pp.; *Statistical Methodology Reviews 1941-1950.* New York: John Wiley and Sons, 1951. 457 pp.

Incidentally, preoccupation with phases of organized research should not overshadow training of the embryo research student at college. Williams asserts:

> The experience of twenty years of undergraduate teaching has shown that college students may be successfully introduced to research work. If the rising generation is to play a leading part in the program of scientific research, much more attention must be paid in the future to arousing the interest of undergraduates in the various fields of science and so inspiring them with the spirit of research. The professions which college men and women follow when they leave college are to a large extent determined by the kind of work which has stimulated them in their undergraduate days.[17]

Special.

Of great number and variety are the institutions specializing in different kinds of research. For descriptive data one may consult the manuals cited under Societies, and also:

Brauer, Ludolph, *et al. Forschungsinstitute; Ihre Geschichte, Organisation, und Ziele.* Hamburg: Paul Hartung, 1930. 2 vols.

All countries and fields of research are covered. Some sections are in English, e.g., the descriptions of the Carnegie Institution of Washington, and the Smithsonian Institution.

American industrial research laboratories are listed in:

National Research Council. *Industrial Research Laboratories of the United States.* (Ninth Edition.) Washington, D. C.: The Council, 1950. 444 pp. (Its *Bulletin,* No. 120, November 1950.)

Areas of specialization are indicated in the following compilation:

University Research Potential; A Survey of the Resources for Scientific and Engineering Research in American Colleges

17. S. R. Williams, *Magnetic Phenomena,* p. ix. New York: McGraw-Hill Book Company, 1931.

and Universities. Evanston, Ill.: Engineering College Research Council, American Society for Engineering Education, 1951. 114 pp.

A *Summary of Resources* is also available. The editor of the survey, J. I. Mattill, reviews the physics findings in "College and University Research in Physics," *Physics Today,* 5 (No. 9): 14-18, September 1952.

Individual research projects are detailed in *Research,* a British journal that commenced publication in 1947; in the *Journal of Research* of our National Bureau of Standards, with summaries in its *Technical News Bulletin;* and in various journals such as the *Physical Review,* the *Journal of Applied Physics,* etc. Some laboratories, notably the National Physical Laboratory (London), have issued reprint and abstract series.

Summary

The scientific method requires that all hypotheses be tested by experimentation, most conveniently (but not exclusively) in the laboratory. Characteristic equipment and associated procedures are described in the books cited, which outline general techniques as well as those adapted to highly specialized areas. Measurement stands out as the fundamental criterion of exact science, and is applied to the various physical entities. The chapter closes with a glance at organized research, which nurtures new developments and puts them to work. Thus do pure and applied science merge.

CHAPTER VI

MATHEMATICAL APPROACH
Physical Constants and Mathematical Tools

Mathematics is not covered here except in its immediate relationship to physics, and other sources[1] must be consulted for more detailed treatment of that subject. Physical constants are numerical entities. They are tabulated in various compilations. These are followed by books that show how to apply mathematics to physics problems, beginning at the modest level of practice in elementary physics, and ascending to the imposing heights of advanced theoretical physics.

Overview

Physics, being an exact science, makes use of numbers and mathematical processes to indicate quantities and interrelationships. The level of difficulty and complexity ranges from simple manipulations of algebraic and trigonometrical formulae to the calculations associated with pure mathematics. Physicists are reluctant, however, to permit such mathematical tools to overshadow experimental techniques and meanings. Thus a well-known textbook is prefaced by the comment.

> The aim throughout the present work has been to treat the matters considered from a physical point of view, and particularly to avoid regarding the material as exercises in applied mathematics.[2]

Even an outstanding physicist like Faraday pleads:

> There is one thing I would be glad to ask you. When a mathematician engaged in investigating physical actions and results has arrived at his own conclusions, may they not be expressed in common language as fully, clearly and definitely as in mathematical formulae? If so, would it not be a great boon to such as we to express them so—trans-

1. Such as Parke's *Guide*; also G. A. Miller, *Historical Introduction to Mathematical Literature.* New York: The Macmillan Company, 1916. 302 pp.
2. F. C. Champion and N. Davy, *Properties of Matter,* p. v. London: Blackie and Son, 1936.

lating them out of their hieroglyphics that we also might work upon them by experiment.[3]

The amount of mathematics utilized in undergraduate textbooks varies from practically none at all in certain very generalized "science surveys" to a maximum in advanced theoretical presentations. Some authors of introductory texts feel that calculus is indispensable, while others[4] have expertly adapted the treatment to students lacking this tool.

Physical quantities are brought within the perspective of everyday life by:

Baravalle, Hermann von. *Zahlen für Jedermann aus Physik und Technik.* Stuttgart: Franckh'sche Verlagshandlung, 1938. 147 pp.

Although usable as a compendium of numerical values of pure physics and technology, its popular appeal stems from interesting comparative grouping. Under Length we find a whole page of values ranging from ultra-microscopic (0.000,004 mm.) to the extent of the Chinese Wall (3,000 Km.); under Temperature are listed typical high values (e.g., electric oven 4,000° C) down to the lowest obtainable (-273° C.). There is a comparative table of speed from walking to flying. Such tabulations stimulate visualization of physical quantities, especially when linked with class work by skillful teachers.

Physical Constants

Tables of physical constants have been included under the Mathematical Approach because of their essentially numerical character. They often appear alongside strictly mathematical tables (functions, logarithms, etc.) in handbooks and compendia.

Handbooks.

Before the standard compendia receive our attention, it may well be centered upon "a new type of handbook, a kind of stu-

3. Letter from Faraday to Maxwell, quoted in A. C. Candler, *Atomic Spectra and the Vector Model,* Vol. 1, t.p. Cambridge, England: At the University Press, 1937.
4. See general textbooks by Sears and Zemansky, and by Stewart and Gingrich.

dent's companion, which he could use to supplement his regular text":

Lindsay, Robert B. *Student's Handbook of Elementary Physics.* New York: Dryden Press, 1943. 382 pp.
Chapters on the various properties of matter are followed by: Illustrated dictionary of terms (pp. 135-270); Chronological table of physics (pp. 271-298); Bibliography of readings (pp. 299-308); Useful formulas (pp. 309-344); Physical constants and mathematical tables (pp. 345-369).

For ordinary purposes, however, one consults the following which are quite similar in their broad coverage of basic physical and chemical data:

a. Chemical Rubber Publishing Company. *Handbook of Chemistry and Physics,* edited by C. D. Hodgman. (34th; 1952-53 Edition.) Cleveland, Ohio: The Company, 1952. 2950 pp. (Revised annually.)

b. Lange, Norbert A. *Handbook of Chemistry; A Reference Volume for All Requiring Ready Access to Chemical and Physical Data.* (Eighth Edition.) Sandusky, Ohio: Handbook Publishers, Inc., 1952. 1998 pp.

Similar compilations often helpful include:

a. Kaye, G. W. C., and Laby, T. H. *Tables of Physical and Chemical Constants and some Mathematical Functions.* (Tenth Edition.) New York: Longmans, Green and Company, 1948. 194 pp.

b. *Smithsonian Physical Tables.* (Eighth Edition.) Washington, D. C.: Smithsonian Institution, 1934. 686 pp.
The rather uneven format is due to the carry-over of individual electrotype plates in successive editions. Geophysical constants receive special emphasis.

c. National Research Council. *Handbook of Physical Constants.* New York: Geological Society of America, 1942. 325 pp. (Geological Society of America, Special Papers, No. 36.)
Besides physical properties of rock and mineral substances, it includes familiar constants for metals, gases, etc.

Representing the ultimate in pocket-size convenience, two *Methuen Monographs* offer a wide assortment of constants and formulas:

a. Childs, W. H. J. *Physical Constants Selected for Stu-*

dents. (Fifth Edition.) New York: John Wiley and Sons, 1949. 77 pp.

b. Thomas, T. S. E. *Physical Formulae.* New York: John Wiley and Sons, 1953. 118 pp.

The latest precise determinations of the atomic constants may be found in:

DuMond, Jesse W. M., and Cohen, E. R. "Least-Squares Adjustment of the Atomic Constants, 1952." *Reviews of Modern Physics,* 25: 691-708, July 1953.

Comprehensive tables.

The small handbooks often fail to yield desired values, especially when a wide range is sought, e.g., at different temperatures. In such instances, one turns to:

National Research Council. *International Critical Tables of Numerical Data, Physics, Chemistry and Technology,* prepared under the auspices of the International Research Council and the National Academy of Sciences by the National Research Council of the United States of America. New York: McGraw-Hill Book Company, 1926-1933. 7 vols. plus index vol.

This major source of physical-chemical properties was compiled by many scientists in various countries. It is arranged according to a rather complicated system explained on page 96 of Volume 1, or more succinctly in Soule's guide.[5] One often finds formulas instead of direct values.

A series of annual tables formed the basis of the *International Critical Tables* and also supplemented them, as follows:

a. *Tables Annuelles de Constantes et Données Numériques de Chimie, de Physique et de Technologie,* années 1910-1934. Paris: Gauthier-Villars, 1912-1937. Vols. 1-11, Part 1; plus collective indexes to vols. 1-5 and 6-10.

Bibliographical mention[6] has been made of "Vol. 12, 1935-6; (One or two parts cover 1931-9)." There is also a related series of monographs.

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5. B. A. Soule, *Library Guide for the Chemist,* pp. 200-202. New York: McGraw-Hill Book Company, 1938.
6. "List of Compendia and Data Tables in Physics," prepared by the Royal Society. *Journal of Documentation,* 7: 252-255, December 1951.

b. *Annual Tables of Physical Constants and Numerical Data.* Princeton, N. J.: Frick Chemical Laboratory, 1941-1942. 2 vols.

This was compiled by the National Research Council's American Committee on Annual Tables. Photo-reproduced pages were accompanied by a card service. The project is inactive at present.

The standard German counterpart of the I. C. T. is currently undergoing revision, requiring temporary use of two editions:

a. *Landolt-Börnstein Physikalisch-Chemische Tabellen.* (Fünfte Auflage.) Berlin: Springer, 1923-1936. 8 vols. as follows: Vols. 1-2, continuously paged, 1923; 1st Supp., 1927; 2nd Supp., Parts 1-2, continuously paged, 1931; 3rd Supp., Parts 1-3, continuously paged, 1935-1936.

In Vol. 1, pp. iv-xiv, may be found a table of contents for the entire set, and a full subject index appears in the last supplementary volume.

b. *Landolt-Börnstein Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik,* herausgegeben von Arnold Eucken. (Sechste Auflage.) Berlin: Springer, 1950- 4 vols. in numerous parts, in process.

Volume titles are as follows: 1, *Atom- und Molekularphysik;* 2, *Makrophysik und Chemie;* 3, *Astronomie und Geophysik;* and 4, *Technik.*

Often useful is a reference set sponsored by the International Union of Pure and Applied Chemistry:

Tables de Constantes et Données Numériques (Constantes Sélectionées). Paris: Hermann et Cie., 1947-1952. 5 vols. (In Process.)

Content is as follows: Part 1, X-ray emission wave lengths; Part 2, Nuclear physics; Part 3, Faraday and Kerr magnetic effects; Parts 4 and 5, Diatomic-molecule spectroscopy.

Special.

The following are examples of specialized compilations:

Gases and vapors

a. Geyer, E. W., and Bruges, E. A. *Tables of Properties of Gases, with Dissociation Theory and its Applications.* New York: Longmans, Green and Company, 1948. 102 pp.

b. Keenan, Joseph H., and Kaye, Joseph. *Gas Tables; Thermodynamic Properties of Air, Products of Combustion, and Component Gases.* New York: John Wiley and Sons, 1948. 238 pp.

c. Keenan, Joseph H., and Keyes, Frederick G. *Thermodynamic Properties of Steam, Including Data for the Liquid and Solid Phases.* New York: John Wiley and Sons, 1936. 89 pp.

Metals

a. *Metals Reference Book,* edited by Colin J. Smithells. New York: Interscience Publishers, Inc., 1949. 751 pp.

b. *Metals Handbook,* edited by Lyman Taylor. (1948 Edition.) Cleveland, Ohio: American Society for Metals, 1948. 1444 pp.

See also the review series, *Progress in Metal Physics.*

Mathematical Tables

As this is a guide primarily to physics literature, no attempt will be made to list mathematical tables in general, especially since this has been admirably accomplished in:

Fletcher, Alan, *et al. An Index of Mathematical Tables.* London: Scientific Computing Service; New York: McGraw-Hill Book Company, 1946. 450 pp.

References in Part 1, which is arranged according to function, are to the bibliography in Part II, pp. 373-444, listing available tables. This index is a great time saver, and points out mathematical compilations that otherwise might be overlooked. For example, on page 83 one learns where to find π correct to 500 decimals!

Computation aids.

Tabular compilations designed to facilitate mathematical processes vary widely. For reducing drudgery in arithmetic there are:

a. Barlow, Peter. *. . . Tables of Squares, Cubes, Square Roots, Cube Roots, and Reciprocals of Numbers up to 12,500,* edited by L. J. Comrie. (Fourth Edition.) London: E. and F. N. Spon, 1941. 258 pp.

b. Allen, Edward S. *Six-place Tables.* (Seventh Edition.) New York: McGraw-Hill Book Company, 1947. 232 pp.
This is a pocket-sized compendium of squares, cubes, square roots, cube roots, logarithms, trigonometric functions, etc.

Conversion factors are helpful, as found in:

a. Zimmerman, O. T., and Lavine, Irvin. *Conversion Factors and Tables.* Dover, N. H.: Industrial Research Service, 1944. 262 pp.

b. Hering, Carl. *Ready Reference Tables, Vol. 1. Conversion Factors of Every Unit or Measure in Use.* New York: John Wiley and Sons, 1914. 196 pp.

For logarithms, the handiest sources of seven-place values are:

a. Vega, Georg. *Logarithmic Tables of Numbers and Trigonometrical Functions,* translated from the 40th revised edition. New York: D. Van Nostrand Company, 19--. 575 pp.

b. Bruhns, Karl. *A New Manual of Logarithms to Seven Places of Decimals.* (Eighteenth Stereotype Edition.) New York: D. Van Nostrand Company, 1939. 610 pp.
This also furnishes logarithms of trigonometric functions. Methods of working with logarithmic tables are described in the introduction, pp. xi-xxiii.

Trigonometric relations are available to four and seven places, respectively, in:

a. Oglesby, Ernest J., and Cooley, Hollis R. *Logarithmic and Trigonometric Tables.* New York: Prentice-Hall, Inc. 1930. 76 pp.

b. Ives, Howard C. *Natural Trigonometric Functions to Seven Decimal Places for Every Ten Seconds of Arc.* (Second Edition.) New York: John Wiley and Sons, 1945. 368 pp.
Subdivision is sufficiently minute for most purposes.

Various general mathematical compendia[7] are available, such as:

a. Burington, Richard S. *Handbook of Mathematical Ta-*

7. Frequently useful is O. W. Eshbach, *Handbook of Engineering Fundamentals.* (Second Edition.) New York: John Wiley and Sons, 1952. Var. paged.

bles and Formulas. (Third Edition.) Sandusky, Ohio: Handbook Publishers, Inc., 1949. 296 pp.

b. Clements, Guy R., and Wilson, Levi T. *Manual of Mathematics and Mechanics.* (Second Edition.) New York: McGraw-Hill Book Company, 1947. 349 pp.

c. Carmichael, Robert D., and Smith, Edwin R. *Mathematical Tables and Formulas.* Boston: Ginn and Company, 1931. 269 pp.

"These tables and formulas have been compiled for the use of students in mathematics courses and in other courses which require numerical computation or involve processes based on mathematics up to and including calculus."

d. Silberstein, L. *Synopsis of Applicable Mathematics, with Tables.* New York: D. Van Nostrand Company, 1923. 250 pp. Formerly known as "Bell's Mathematical Tables," this collection includes formulae, definitions, theorems, and functions.

Functions.

Integrals are conveniently tabulated in:

a. Peirce, B. O. *A Short Table of Integrals.* (Third Edition.) Boston: Ginn and Company, 1929. 156 pp.

b. Dwight, Herbert B. *Tables of Integrals and Other Mathematical Data.* (Revised Edition.) New York: The Macmillan Company, 1947. 250 pp.

c. Bierens de Haan, D. *Nouvelles Tables d'Intégrales Définies.* New York: G. E. Stechert and Company, 1939. 716 pp. (This is based on the 1867 edition, and has a translation of the introduction.)

The most frequently helpful general collections of mathematical functions are:

a. Jahnke, Eugene, and Emde, Fritz. *Tables of Functions with Formulae and Curves.* (Fourth Edition.) New York: Dover Publications, 1945. 379 pp.

Explanatory text is in German and English. "The new edition differs from all previous editions in providing all material contained in the last edition of 1938, plus a 76 page section on 'Tables of Elementary Functions' . . . originally published in the now out-of-print 1933 edition."

b. Dwight, H. B. *Mathematical Tables of Elementary and*

Some Higher Mathematical Functions. New York: McGraw-Hill Book Company, 1941. 231 pp.

Special collections of functions may be represented by:

a. Harvard University Computation Laboratory. *Tables of the Bessel Functions of the First Kind of Orders.* Cambridge, Mass.: Harvard University Press, 1947-1951. (Its *Annals,* Vols. 3-14.)

b. Gray, Andrew, and Mathews, G. B. *A Treatise on Bessel Functions*[8] *and Their Applications to Physics.* (Second Edition.) London: The Macmillan Company, 1922. 327 pp.

c. Stratton, J. A., *et al. Elliptic Cylinder and Spheroidal Wave Functions.* New York: John Wiley and Sons, 1941. 127 pp.

See also the various tables of the New York Mathematical Tables Project, listed in Parke.[9]

Applied Mathematics

This section deals with physics applications of mathematics, over the extremely wide range from elementary problem solving to advanced theoretical physics.

Problems.

Mathematical solution in general is discussed from several viewpoints by:

a. Dadourian, H. M. *How to Study; How to Solve (Arithmetic through Calculus).* (New Edition.) Cambridge, Mass.: Addison-Wesley Press, 1951. 121 pp.

b. Kogan, Zuce. *Essentials in Problem Solving.* Chicago: The Author, 1951. 79 pp.

c. Polya, G. *How to Solve It; A New Aspect of Mathematical Method.* Princeton, N. J.: Princeton University Press, 1948. 224 pp.

Physics problem books vary widely, some giving detailed solutions, while others merely state the questions. Two com-

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8. For a shorter survey, see T. A. Benham, "Bessel Functions in Physics." *American Journal of Physics,* 15: 285-294; 488-497, July-August and November-December, 1947.
9. N. G. Parke, *op. cit.,* pp. 135-136.

pilations most helpful to students because theoretical summaries are accompanied by worked-out solutions are:

a. Schaum, Daniel. *Outline of Theory and Problems for Students of College Physics.* (Fifth Edition.) New York: Schaum Publishing Company, 1946. 212 pp.
This is very popular because of its clear presentation and its large number of detailed solutions.

b. Harty, John, and Weber, A. H. *How to Solve Problems in General Physics.* Part 1. St. Louis, Mo.: Educational Publishers, Inc., 1950. 112 pp.
This volume covers mechanics, hydrostatics, heat and thermodynamics; a second (in preparation) will treat light and electricity.

Similar collections with fewer illustrative examples are:

a. Henderson, William D. *Problems in Physics for Technical Schools, Colleges, and Universities.* (Second Edition.) New York: McGraw-Hill Book Company, 1931. 245 pp.

b. Masius, Morton. *Problems in General Physics for College Courses.* (Second Edition.) Philadelphia: P. Blakiston's Son and Company, 1924. 154 pp.

c. Stephenson, Reginald J. *Exploring in Physics; A New Outlook on Problems in Physics.* Chicago: University of Chicago Press, 1935. 205 pp.
This is an interesting and attractive problem book designed to accompany Lemon's "From Galileo to Cosmic Rays," the predecessor of his "From Galileo to the Nuclear Age." Problems within the range of students' experience are presented informally, with cartoon illustrations.

d. Taylor, Lloyd W. *A Numerical Drill Book on Physics.* Boston: Ginn and Company, 1926. 95 pp.
Four sets of data are tabulated for each problem, with answers in last column.

e. Miller, Fred R. *Progressive Problems in Physics.* (Sixth Edition.) Boston: D. C. Heath and Company, 1949. 237 pp.
The level is midway between high school and college. No answers are furnished.

Special problem books are available for certain fields, such as:

a. Karelitz, G. B.; Ormondroyd, J.; and Garrelts, J. M. *Prob-*

lems in Mechanics, based on the original collection of I. V. Mestchersky. New York: The Macmillan Company, 1939. 271 pp.
Theory is summarized, pp. 1-50, and sample solutions are provided for one-tenth of the problems.

b. Perrin, Fred H. *Five Hundred Problems in Optics.* (Second Edition.) Ann Arbor, Mich.: Edwards Brothers, 1942. 37 pp.

c. Faires, Virgil M., and Brewer, A. V. *Problems on Applied Thermodynamics.* New York: The Macmillan Company, 1938. 137 pp.

Theoretical physics.

When advanced mathematical reasoning is applied to physical theory so as to derive new concepts that can be verified experimentally, the process is termed mathematical or theoretical physics. Although its wonders may be obscured to many by the complicated mathematics involved, it is not too distant from reality, as Slater and Frank state:

> The same ability to overcome obstacles, the same ingenuity in devising one method of procedure when another fails, the same physical intuition leading one to perceive the answer to a problem through a mass of intervening detail, the same critical judgment leading one to distinguish right from wrong procedures, and to appraise results carefully on the grounds of physical plausibility, are required in theoretical and in experimental physics. Leaks in vacuum circuits or in electric circuits have their counterparts in the many disastrous things that can happen to equations. And it is often as hard to devise a mathematical system to deal with a difficult problem, without unjustifiable approximations and impossible complications, as it is to design apparatus for measuring a difficult quantity or detecting a new effect. These things cannot be taught. They come only from that combination of inherent insight and faithful practice which is necessary to the successful physicist. But half the battle is over if the student approaches theoretical physics not as a set of mysterious formulas, or as a dull routine to be learned, but as a collection of methods, of tools, of apparatus, subject to the same sort of rules as other physical apparatus, and yielding results of great importance.[10]

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10. J. C. Slater and N. H. Frank, *Introduction to Theoretical Physics,* p. vii. New York: McGraw-Hill Book Company, 1933.

The development of mathematical or theoretical physics is ably traced by:

Abro, A. d'. *Rise of the New Physics; Its Mathematical and Physical Theories.* (Second Edition.) New York: Dover Publications, 1951. 2 vols.

This was formerly titled *Decline of Mechanism (in Modern Physics).*

An interesting discussion of the role of the mathematical physicist is afforded by:

Milne, E. A. *The Aims of Mathematical Physics.* Oxford: At the Clarendon Press, 1929. 28 pp.

Excellent general surveys include:

a. Joos, Georg. *Theoretical Physics.*[11] (Second Edition.) London: Blackie and Son, 1951. 853 pp.

b. Lindsay, Robert B. *Concepts and Methods of Theoretical Physics.* New York: D. Van Nostrand Company, 1951. 515 pp.

c. Jeffreys, Harold, and Jeffreys, Bertha S. *Methods of Mathematical Physics.* (Second Edition.) Cambridge, England: At the University Press, 1950. 708 pp.

d. Slater, John C., and Frank, N. H. *Introduction to Theoretical Physics.* New York: McGraw-Hill Book Company, 1933. 576 pp.

e. Page, Leigh. *Introduction to Theoretical Physics.* (Third Edition.) New York: D. Van Nostrand Company, 1952. 701 pp.

f. Houston, William V. *Principles of Mathematical Physics.* (Second Edition.) New York: McGraw-Hill Book Company, 1948. 363 pp.

For more extensive multi-volume treatment, see:

Sommerfeld, Arnold. *Lectures on Theoretical Physics.* New York: Academic Press, 1949- 6 vols. (In process.)

Further help with applied mathematical techniques is obtainable from:

a. Margenau, Henry, and Murphy, George M. *The Mathe-*

11. The German edition is titled *Lehrbuch der Theoretischen Physik.* (Siebte Auflage.) Leipzig: Geest & Portig, 1950. 766 pp.

matics of Physics and Chemistry. New York: D. Van Nostrand Company, 1943. 581 pp.

b. Sokolnikoff, Ivan S., and Sokolnikoff, E. S. *Higher Mathematics for Engineers and Physicists.* (Second Edition.) New York: McGraw-Hill Book Company, 1941. 587 pp.

c. Pipes, Louis A. *Applied Mathematics for Engineers and Physicists.* New York: McGraw-Hill Book Company, 1946. 618 pp.

d. Schelkunoff, S. A. *Applied Mathematics for Engineers and Scientists.* New York: D. Van Nostrand Company, 1948. 472 pp.

e. Burington, Richard S., and Torrance, C. C. *Higher Mathematics, with Applications to Science and Engineering.* New York: McGraw-Hill Book Company, 1939. 844 pp.

Comprehensive collections of formulae useful in theoretical physics are presented in:

a. Madelung, Erwin R. *Die Mathematischen Hilfsmittel des Physikers.* (Vierte Auflage.) Berlin: Springer, 1950. 531 pp.

This useful collection is widely used.

b. Magnus, Wilhelm, and Oberhettinger, F. *Formulas and Theorems for the Special Functions of Mathematical Physics.* New York: Chelsea Publishing Company, 1949. 172 pp.

Examples of special tools in mathematical physics are:

a. Berg, Ernst J. *Heaviside's Operational Calculus as Applied in Engineering and Physics.* (Second Edition.) New York: McGraw-Hill Book Company, 1936. 258 pp.

b. Churchill, Ruel V. *Fourier Series and Boundary Value Problems.* New York: McGraw-Hill Book Company, 1941. 206 pp.

c. Bateman, H. *Partial Differential Equations of Mathematical Physics.* Cambridge, England: At the University Press, 1932. 522 pp.

(There is also a Dover Publications reprint, 1944.)

Statistical techniques are applied to physics in:

a. Lindsay, Robert B. *Introduction to Physical Statistics.* New York: John Wiley and Sons, 1941. 306 pp.

Lindsay states (p. v):

In this book the attempt has been made to survey as thoroughly as

possible the various ways in which statistical reasoning has been used in physics from the classical applications to fluctuation phenomena, kinetic theory, and statistical mechanics to the contemporary quantum mechanical statistics. Emphasis has been laid on methodology.

b. Landau, L., and Lifshitz, E. *Statistical Physics.* Oxford: At the Clarendon Press, 1938. 234 pp.

c. Fowler, Ralph H., and Guggenheim, E. A. *Statistical Thermodynamics; A Version of Statistical Mechanics for Students of Physics and Chemistry.* New York: The Macmillan Company, 1939. 693 pp.

d. Gurney, Ronald W. *Introduction to Statistical Mechanics.* New York: McGraw-Hill Book Company, 1949. 268 pp.

Further aid with statistical mathematics may be derived from Bacon's résumé,[12] and from such books as:

a. Fisher, Ronald A. *The Design of Experiments.* (Fifth Edition.) New York: Hafner Publishing Company, 1949. 242 pp.

b. Aitken, A. C. *Statistical Mathematics.* (Fifth Edition.) New York: Interscience Publishers, Inc., 1947. 161 pp.

See also Worthing and Geffner's *Treatment of Experimental Data,* and the *Statistical Methodology Reviews.*

Advanced mathematical treatments of physical phenomena are scattered among sections of this guide in the Topical Approach. However, two impressive areas of theoretical physics may herewith be mentioned as examples:

Quantum or wave mechanics

Electron radiation possesses both wave and discrete-particle attributes, as outlined in:

a. Frenkel, J. *Wave Mechanics; Elementary Theory.* (Second Edition.) Oxford: At the Clarendon Press, 1936. 312 pp. (This volume, and one on advanced theory, have been reprinted by Dover Publications, 1950.)

b. Mott, N. F. *Elements of Wave Mechanics.* Cambridge, England: At the University Press, 1952. 156 pp.

c. Dirac, Paul A. M. *The Principles of Quantum Mechanics.*

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12. R. H. Bacon, "Practical Statistics for Practical Physicists." *American Journal of Physics,* 14: 84-98; 198-209, March-April and May-June, 1946.

(Third Edition.) Oxford: At the Clarendon Press, 1947. 311 pp.

d. Slater, John C. *Quantum Theory of Matter.* New York: McGraw-Hill Book Company, 1951. 528 pp.

e. Persico, Enrico. *Fundamentals of Quantum Mechanics.* New York: Prentice-Hall, Inc., 1950. 484 pp.

See also Sommerfeld's *Wave Mechanics,* and Coulson's *Waves.*

Relativity

Einstein's theory postulates that motion through free space is relative rather than absolute, and that the velocity of light is independent of source velocity. (The special theory of relativity shows that mass, i.e., inertia, varies with velocity.) Physicists may read the originator's own summary in:

Einstein, Albert. *The Meaning of Relativity.* (Fourth Edition.) Princeton, N. J.: Princeton University Press, 1953. 165 pp.

The beginner had better start with:

a. Lieber, Lillian R. *The Einstein Theory of Relativity.* New York: Rinehart and Company, 1945. 324 pp.

b. Bergmann, Peter G. *Introduction to the Theory of Relativity.* New York: Prentice-Hall, Inc., 1942. 287 pp.

This textbook covers mathematical and physical aspects, and is prefaced by a foreword written by Einstein. Its three parts are: Special theory of relativity; General theory of relativity; Unified field theories.

An advanced account of the theory has recently been published:

Møller, C. *The Theory of Relatively.* London: Oxford University Press, 1952. 386 pp.

For the necessary mathematics, one may turn to:

Rainich, G. Y. *Mathematics of Relativity.* New York: John Wiley and Sons, 1950. 173 pp.

A comprehensive bibliography is available:

Lecat, Maurice. *Bibliographie de la Relativité.* Bruxelles: Maurice Lamertin, 1924. 290; 47 pp.

Arrangement is alphabetical by author, with each item numbered in square brackets. See "Table des Matières" (p. ix) for various component lists and index approaches, eg., by peri-

odical in which article had appeared; chronological history of articles by their dates (from 1728 to 1924).

Summary

While mathematics furnishes many necessary tools to science, it must not presume to overshadow physical meanings and concepts. Fletcher, *et al.*, have listed mathematical tables of all kinds. Compendia of physical constants, essentially numerical, also vary widely from the Childs booklet to the monumental Landolt-Börnstein work. Applied mathematics has been discussed from the standpoints of technique in elementary problem solving as well as formulation of the subject content of advanced theoretical physics, notably quantum mechanics and relativity.

CHAPTER VII

EDUCATIONAL APPROACH
Study, Teaching, and Educational Research

The educational approach signifies desire to consult sources of information on the theory and practice of physics teaching, embracing a wide range of material from research to popularized treatments of the subject content of physics, which contribute to general education if soundly conceived.

Overview

The old psychology of physics teaching placed too much emphasis upon memorization of miscellaneous subject material. Whether the material figured importantly in life was unimportant. Interrelationships among diverse items were not brought out clearly. Mental discipline and training of the faculties received undue stress, in the mistaken belief that the degree of transfer value from one field to another was exceedingly high.

Today the needs and interests of the learner are prime criteria. Whatever will help students meet life's exigencies is included in curricula, rather than masses of accumulated facts for their own sake. Clear constructive thinking and purposeful action are to be cultivated. All knowledge is to be integrated by delineating significant interrelationships and arriving at conclusive generalizations.

> Science education is applying the methods of science to its own procedures, and is making substantial progress in the direction of placing science as a subject in the curriculum on a much firmer and more scientific basis than it has ever been before. Attention is being directed toward the problem of seeing what science instruction can do to fit people for better and more complete living in present-day society instead of its being directed toward an *a priori* justification of it.[1]

The various books on the study and teaching of physical sci-

1. V. H. Noll, *The Teaching of Science in Elementary and Secondary Schools*, pp. 6-7. New York: Longmans, Green and Company, 1942.

ence mentioned later in this chapter embrace this enlightened viewpoint, including those of less recent publication date, which were evidently forerunners of the new era.

Early period.

McCarthy has written an interesting description[2] of the beginnings of physics teaching in American colleges. Conditions over a century later (1880) are depicted in the following governmental circulars:

a. Clarke, Frank W. *A Report on the Teaching of Chemistry and Physics in the United States.* Washington, D. C.: Government Printing Office, 1881. 219 pp. (U. S. Bureau of Education, Circular of Information No. 6, 1880.)
Activities of particular institutions are described, and early textbooks are listed (pp. 157-166).

b. Wead, Charles K. *Aims and Methods of the Teaching of Physics.* Washington, D. C.: Government Printing Office, 1884. 158 pp. (U. S. Bureau of Education, Circular of Information No. 7, 1884.)
This presents well-arranged material on physics teaching practices at all levels, collected from a wide range of sources, and developing an interesting picture of the period.

Transition.

The following survey reveals science teaching in 1932 to be a mixture of old and new practices:

Beauchamp, Wilbur L. *Instruction in Science.* Washington, D. C.: Government Printing Office, 1933. 63 pp. (U. S. Office of Education Bulletin 1932, No. 17, Monograph No. 22.)
Secondary school practices are extensively surveyed, showing trends towards better educational ideas and methods, such as development of major concepts, project method, visual aids, etc.

Recent period.

A history of science teaching incorporating recent trends is:

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2. J. J. McCarthy, "Physics in American Colleges Before 1750." *American Physics Teacher*, 7: 100-104, April 1939.

Underhill, Orra E. *The Origins and Development of Elementary School Science.* Chicago: Scott, Foresman and Company, 1941. 347 pp.
Methods and textbooks are surveyed from 1750 to 1939.

Further historical summaries may be found in Mann, Rusk and Hunter, cited below, and in Roller's survey article.[3]

Study and Teaching

Sound teaching principles and techniques may be derived from books on science teaching in general, as well as those centered exclusively upon physics.

Physics teaching.

Although somewhat lacking in desired recency, the following are helpful books on the teaching of physics *per se:*

a. Rusk, Rogers D. *How to Teach Physics.* Philadelphia: J. B. Lippincott Company, 1923. 186 pp.
The author maintains that physics teaching should be integrated with life needs, displaying an enlightened viewpoint for the period.

b. Mann, C. Riborg. *The Teaching of Physics for Purposes of General Education.* New York: The Macmillan Company, 1922. 304 pp.
Humanizing of physics is advocated. Historical aspects are well treated.

Science teaching.

Interesting overall surveys of science education are provided by:

a. Noll, Victor H. *The Teaching of Science in Elementary and Secondary Schools.* New York: Longmans, Green and Company, 1942. 238 pp.
This is a comprehensive digest of current thought and published writings on science teaching. It has lengthy bibliographies on such topics as objectives, scientific attitude, laboratory

3. D. Roller, "The Role of the Sciences in General Education." *American Physics Teacher,* 6: 244-253, October 1938.

vs. lecture demonstration, etc. In the appendix, pp. 222-227, are listed the best objective tests in physics.

b. Cohen, I. Bernard, and Watson, Fletcher G. *General Education in Science.* Cambridge, Mass.: Harvard University Press, 1952. 217 pp.

Background materials are featured in:

a. Richardson, John S., and Cahoon, G. P. *Methods and Materials for Teaching General and Physical Science.* New York: McGraw-Hill Book Company, 1951. 485 pp.

The authors show how to enrich high school and introductory college science courses, with emphasis upon physics. Demonstrations, experiments and projects are presented, and sources indicated.

b. Heiss, Elwood D.; Obourn, E. S.; and Hoffman, C. W. *Modern Science Teaching.* New York: The Macmillan Company, 1950. 462 pp.

This is a revision of the authors' earlier *Modern Methods and Materials for Teaching Science,* and is intended as both a textbook in science education and a source book of equipment and sensory aids.

c. Woodring, Maxie N., *et al. Enriched Teaching of Science in High School.* (Second Edition.) New York: Bureau of Publications, Teachers College, Columbia University, 1941. 402 pp.

See also the lecture demonstrations, audio-visual materials, etc., mentioned under Presentational Approach in Chapter IX.

Less recent, but still valuable, are the following:

a. Hurd, Archer W. *Problems of Science Teaching at the College Level.* Minneapolis: University of Minnesota Press, 1929. 195 pp.

This is a scholarly statistical study in testing methods for college physics.

b. Brownell, Herbert, and Wade, Frank B. *The Teaching of Science and the Science Teacher.* New York: The Century Company, 1925. 322 pp.

c. Hunter, George W. *Science Teaching at Junior and Senior High School Levels.* New York: American Book Company, 1934. 552 pp.

It has extensive bibliographies of reference materials, and a good historical survey of science teaching.

d. Twiss, George R. *Textbook in the Principles of Science Teaching.* (Revised Edition.) New York: The Macmillan Company, 1927. 486 pp.

For the beginner teacher, fundamentals are presented in:

Preston, Carleton E. *The High School Science Teacher and His Work.* New York: McGraw-Hill Book Company, 1936. 272 pp.

Testing devices[4] are discussed in books by Noll, Heiss, *et al.,* above, and in a comprehensive report:

"Measuring the Results of Instruction in College Physics." (A summary report on the National College Physics Testing Program, 1933-1939.) *American Journal of Physics,* 8: 173-181, June 1940.

Four previous reports are mentioned in a footnote (p. 174).

Objectives and evaluation are further delineated in several articles.[5]

Society publications.

From time to time, learned societies issue general surveys:

a. National Society for the Study of Education. *A Program for Teaching Science.* Bloomington, Ill.: Public School Publishing Company, 1932. 364 pp. (Its *Thirty-First Yearbook,* Part I.)

This is the report of a committee headed by Professor S. Ralph Powers, dealing with the new psychology of science teaching. Integration of all courses from elementary school to college, and fulfilment of vital needs and interests of pupils were empha-

4. *See also* lists in G. H. Hildreth, *A Bibliography of Mental Tests and Rating Scales,* pp. 163-165. (Second Edition.); *1945 Supplement,* pp. 44-45. New York: The Psychological Corporation, 1939-1946.

5. L. Nedelsky, "Formulation of Objectives of Teaching in the Physical Sciences." *American Journal of Physics,* 17: 345-354, September 1949;

A. W. Smith, R. W. Tyler, and L. M. Heil, "Evaluation of Student Achievement in the Physical Sciences." *American Physics Teacher,* 5: 102-107, June 1937; *Ibid,* 6: 62-66, April 1938.

sized in this important discussion of enlightened practices in science instruction at all levels.

b. Progressive Education Association. Commission on Secondary School Curriculum. *Science in General Education.* Suggestions for Science Teachers in Secondary Schools and the Lower Division of Colleges. New York: D. Appleton-Century Company, 1938. 591 pp.
Fully documented, it outlines the role of general education in preparation for life in a democratic society.

c. *Reorganization of Science in Secondary Schools.* A Report of the Commission on the Reorganization of Secondary Education, appointed by the National Education Association. Washington, D. C.: Government Printing Office, 1920. 62 pp. (U. S. Bureau of Education Bulletin 1920, No. 26.)
Recommended practices to bring physics teaching into contact with needs and interests are outlined, pp. 49-60.

Societies also issue special surveys, like the following:

a. American Physical Society. *The Teaching of Physics, with Special Reference to the Teaching of Physics to Students of Engineering.* New York: The Society, 1922. 55 pp.
Its contents include: Purpose of physics in an engineering college; Methods of instruction in physics (lecture, recitation and laboratory); Defects of present methods as seen by others; Coordination of physics and other subjects in engineering colleges.

b. Mathematical Association. *The Teaching of Mechanics in Schools.* London: G. Bell and Sons, 1930. 84 pp.
Concrete suggestions are given for relating mechanics to everyday life, rather than general philosophical aspects.

c. Physical Society. *Teaching of Geometrical Optics.* London: The Society, 1934. 86 pp.

d. American Association of Physics Teachers. "The Teaching of Geometrical Optics." *American Physics Teacher,* 6: 78-82, April 1938.

e. American Association of Physics Teachers. "The Teaching of Electricity and Magnetism at the College Level." *American Journal of Physics,* 18: 1-25; 69-88, January and February 1950.

Periodicals.

A discussion of the periodicals of interest to the physicist was given in Chapter II of this guide. From the educational viewpoint, the most fruitful source of articles on physics teaching at the college level is the *American Journal of Physics*, (formerly the *American Physics Teacher*). For elementary and secondary education, the corresponding source is *School Science and Mathematics.* Indexing media for contents of journals are *Industrial Arts Index* and *Education Index.* (Unfortunately, *Physics Abstracts* does not bother to include in its indexing any general articles, i.e., articles on other than the topics of physics *per se.*) For further information on serial indexes, refer to Chapter II of this guide, and to Chapter VI and VII of Alexander, cited below under Educational Research.

Bibliographies.

Extensive references on science teaching may be derived from:

a. Glenn, Earl R., and Walker, Josephine. *Bibliography of Science Teaching in Secondary Schools.* Washington, D. C.: Government Printing Office, 1925. 161 pp. (U. S. Office of Education Bulletin 1925, No. 13.)

This is valuable because it analyzes selected periodicals prior to the beginning of *Education Index* in 1929. Physics is covered on pp. 132-160.

b. Monroe, Walter S., and Shores, Louis. *Bibliographies and Summaries in Education to July, 1935.* New York: The H. W. Wilson Company, 1936. 470 pp.

c. Hollingsworth, J. R. "Abridged Bibliography of Studies Pertaining to Science Teaching." *American Journal of Physics,* 9: 297-303, October 1941.

A numbering scheme groups the references under sixty topics, e.g., Rote Learning; Lecture Method.

Current bibliographies are offered by the *Bibliographic Index,* previously noted. Under the headings "Physics—Study and Teaching" and "Science—Study and Teaching" may be found relevant books in the *Cumulative Book Index.* Incidentally, *Education Index* lists books (as well as periodical articles), under these same headings.

Study.

Shifting emphasis from teacher to pupil, one finds the complementary aspect of effective study helpfully presented in these manuals:

a. Chapman, Seville. *How to Study Physics.* (Revised Edition.) Cambridge, Mass.: Addison-Wesley Press, 1949. 32 pp.

b. Sanford, Fernando. *How to Study; Illustrated through Physics.* New York: The Macmillan Company, 1922. 56 pp.

c. Crawford, Claude C. *Studying the Major Subjects.* Los Angeles, Cal.: University of Southern California, 1930. 384 pp. Physics and chemistry are jointly treated, pp. 129-159.

Reading skill is basic to effective study, and may be stimulated by:

Howland, Hazel P.; Jarvie, L. L.; and Smith, L. F. *How to Read in Science and Technology.* New York: Harper and Brothers, 1943. 264 pp.

Sections include: Reading for details; Reading for main ideas; Reading to understand principles; Reading to follow directions; Reading to solve a problem; Reading to understand and interpret graphical materials. Selected passages are presented, followed by exercises thereon.

Additional help in forming desirable study habits may be obtained from Chapter I, "The Principles of Reading and Study," in Parke. *See also* Dadourian's *How to Study; How to Solve,* and pp. xi-xv of Lindsay's *Student's Handbook.*

Popularization.

It is salutary for those associated with educational institutions to be reminded occasionally that general education is not confined to the classroom. Self-teaching on an informal and entirely voluntary basis is open to all who possess the ambition and persistence to learn. Dingle[6] even goes further in stating that "when the terms employed are clearly defined and the sentences used are unambiguous, the mental grasp of the educated layman is not inferior to that of the scientist."

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6. Herbert Dingle, *Modern Astrophysics,* p. x. (Second Edition.) New York: The Macmillan Company, 1927.

The printed materials likely to reach laymen have been the topic of scholarly investigations like the following:

a. Mohr, Jennie. *A Study of Popular Books on the Physical Sciences.* New York: The Author, 1942. 107 pp. (Columbia University Ph. D. Dissertation.)

Purposes and techniques of literature written to communicate science in popular fashion are analyzed.

b. Novak, Benjamin J. *An Analysis of the Science Content of the New York Times and of Selected General Science Textbooks.* Philadelphia: Temple University, 1942. 60 pp. (Doctoral Dissertation.)

The character of "newspaper science" is delineated.

Only three attractive subject matter presentations need be cited among many:

a. Harrison, George R. *Atoms in Action; The World of Creative Physics.* (Third Edition.) New York: William Morrow and Company, 1949. 406 pp.

This popular exposition covers the whole range of physics, under such chapter headings as "Sight Conquers Space" (television).

b. Hogben, Lancelot T. *Science for the Citizen.* (New Edition.) New York: W. W. Norton and Company, 1951. 1146 pp.

c. Carter, Ernest F. *Physics for Everyone; 1001 Physics Questions and Answers.* London: Burke Publishing Company, 1951. 223 pp.

Questions are grouped under such headings as Motion, Magnetism, Nuclear Physics, etc. Typical ones are: What is kinetic energy? What causes an echo? Why is the sky blue? What is the average size of a molecule?

Popular fallacies are dispelled in the following compilations:

a. Ackermann, Alfred S. E. *Popular Fallacies; A Book of Common Errors Explained and Corrected.* (Fourth Edition.) London: Old Westminster Press, 1950. 843 pp.

For example, one would find in this compilation such false physics notions as warm water freezing faster than cold on wintry pavements.

b. Hampson, W. *Paradoxes of Nature and Science.* New York: E. P. Dutton and Company, 1907. 304 pp.

c. Hering, Daniel W. *Foibles and Fallacies of Science.* New York: D. Van Nostrand Company, 1924. 294 pp.

d. Phin, John. *The Seven Follies of Science.* London: Arnold Constable and Company, 1906. 178 pp.

Phin relates the most famous scientific impossibilities, notably perpetual motion.

e. Dircks, Henry. *Perpetuum Mobile; Or, Search for Self-Motive Power, during the 17th, 18th, and 19th Centuries.* London: E. and F. N. Spon, 1861. 558 pp.

Scientific analyses of psychic phenomena are undertaken in:

a. Still, Alfred. *Borderlands of Science.* New York: Philosophical Library, 1950. 424 pp.

The author states (p. 1):

> This book is not a history of science; neither is it a history of magic; it is an attempt to evaluate the influence on civilization of both science and superstition—knowledge and belief, and to consider critically those "borderland" phenomena which the scientist rarely investigates notwithstanding that they occur in the natural world which he shares with the unreasoning multitude.

Some of the chapters are: Science and the scientist; Magic and the mystic; Witchcraft and the new science; The divining rod; Levitation; Hypnotism and clairvoyance; Telepathy.

b. Tromp, Solco W. *Psychical Physics.* New York: Elsevier Publishing Company, 1949. 534 pp.

As a geologist, the author encountered many dowsers—people claiming the power to use divining rods to discover water or underground deposits. He examines evidence of the influence of electromagnetic fields on living organisms, with respect to divining and similar phenomena.

Pseudo-science and quackery are exposed in:

Gardner, Martin. *In the Name of Science.* New York: G. P. Putnam's Sons, 1952. 320 pp.

(For students' misconceptions in physics, see lists[7] by Perkins, *et al.*)

Educational Research

Before special research is attempted in science education,

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7. *American Journal of Physics,* 11: 101-102; 163-165; 227-228, April-August 1943.

procedural guidance in general educational research should be obtained from the following:

a. Alexander, Carter, and Burke, Arvid J. *How to Locate Educational Information and Data.* (Third Edition.) New York: Bureau of Publications, Teachers College, Columbia University, 1950. 441 pp.

This is an outstanding example of the art of guide compilation. It surveys all types of library materials, and outlines most efficient utilization.

b. *Encyclopedia of Educational Research*, edited by Walter S. Monroe. (Revised Edition.) New York: The Macmillan Company, 1950. 1520 pp.

Of particular interest is the section, "Science Education."

c. Whitney, Frederick L. *The Elements of Research.* (Third Edition.) New York: Prentice-Hall, Inc., 1950. 539 pp.

d. Good, Carter V.; Barr, A. S.; and Scates, Douglas E. *The Methodology of Educational Research.* New York: D. Appleton-Century Company, 1936. 882 pp.

Comprehensive digests.

As a review of published research in the teaching of science from early in the century to the year 1937, the following series of digests is invaluable, not only for listings of research studies but especially for keen analyses under headings of problem, method, findings, etc. To date, three have appeared:

Curtis, Francis D. *A Digest of Investigations in the Teaching of Science.* Philadelphia: Blakiston and Company, 1926. 341 pp.

Research investigations published prior to 1925 are included.

Curtis, Francis D. *Second Digest...* Philadelphia: Blakiston and Company, 1931. 424 pp. (Covering 1925 through 1930.)

Curtis, Francis D. *Third Digest...* Philadelphia: Blakiston and Company, 1939. 419 pp. (Covering 1931 through 1937.)

These compilations, which include supplementary bibliographies as well as outlines of selected researches, are indispensable to research workers, science teachers and school administrators.

General lists.

For research lists of most general nature, the section Dissertations should be consulted.

The narrower field of educational research is spanned chronologically by the following:

a. Monroe, Walter S. *Ten Years of Educational Research, 1918-27.* Urbana, Ill.: University of Illinois, 1928. 377 pp. (University of Illinois, Bureau of Educational Research, Bulletin No. 42, August 1928.)

b. U. S. Office of Education. *Bibliography of Research Studies in Education, 1926-27 — 1939-40.* Washington. D. C.: Government Printing Office, 1929-1942. Vols. 1-14. (Its *Bulletin* 1928-1941.)

See especially the "Chemistry and Physics" sections.

Current educational research studies may be found in *Education Index,* the *Review of Educational Research,* and the *Journal of Educational Research.* (In the latter journal, Carter V. Good has been listing dissertations in progress, each January issue from 1931 to 1946; thereafter in the March *Phi Delta Kappan.*)

Individual studies.

Good examples of separate research investigations on phases of science education are to be found among the *Contributions to Education* published by Teachers College, Columbia University. A few in the series, chosen more or less at random, indicate types available:

No. 163: Curtis, F. D. *Some Values derived from Intensive Reading of General Science.* 1924.

No. 553: Clemensen, J. W. *Study Outlines of Physics.* 1933.

No. 725: Efron, A. *Teaching of Physical Sciences in the Secondary Schools of the United States, France and Soviet Russia.* 1937.

No. 840: Kilgore, W. A. *Identification of the Ability to Apply Principles of Physics.* 1941.

Summary

Physics teaching has gradually joined the trend away from mere rote-learning to real-life significance as determined by

needs and interests. The various textbooks, surveys and current records cited provide helpful suggestions on how to teach. Conversely, how to study is explored in several booklets written from the learner's viewpoint. Popularization of physics content (without distortions and inaccuracies) is sound introductory procedure. For educational research, Alexander's comprehensive guide covers existing sources of data and their efficient use, as steps towards still further knowledge and developments.

CHAPTER VIII

TERMINOLOGICAL APPROACH
Definitions and Translations

When one seeks definitions of terms, or assistance in translating them, he follows the terminological approach. Abbreviations and symbols are related entities.

Overview

"A definition of a term or quantity is an expression stated in simpler or more fundamental terms or quantities, that may replace the original term or quantity wherever used without loss or change of thought."[1]

Roller has prepared an interesting discussion of the idiosyncrasies of physical terms:

Roller, Duane E.[2] *The Terminology of Physical Science.* Norman, Okla.: University of Oklahoma Press, 1929. 115 pp. The chapters are: Physical terms and their definitions; Common prefixes and suffixes; Names of the chemical elements; Pronunciation of words used in science; Spelling of words used in science; Simpler standard abbreviations. Teachers and textbook writers are urged to avoid careless or ambiguous terminology which proves troublesome to students.

Structure of scientific terms, especially in the biological sciences, is also surveyed by:

Hough, John N. *Scientific Terminology.* New York: Rinehart and Company, 1953. 231 pp.
This treats the formation of English words from roots, stems, prefixes and suffixes of Latin and Greek origin.

Every field of activity has its body of accepted meanings,

1. A. G. Worthing, "A Simple Test for the Preciseness of a Definition." *American Physics Teacher*, 6: 59-61, April 1938.
2. See also his "An Approach to the Study of Physical Terminology." *American Journal of Physics*, 15: 178-186, March-April 1947.

even the art of bell-ringing, from which Taylor quotes an interesting passage:

> A plain course in any method may be extended into a touch or even a peal by calling a series of bobs or singles or both. When a bob is called, the bell that was about to make seconds runs out quick and lies behind for a whole pull. The bell that was about to dodge in 3-4 down hunts down instead and turns the treble from lead. . . . The beginner should familiarize himself with the composition of touches by repeatedly pricking changes until he can dependably bring the bells into rounds from any lead-end at which he may start.[3]

These directions seem simple and matter-of-fact to a bell ringer, because he is quite familiar with the terms. Definitions must thus be learned before one may proceed intelligently with practical or theoretical work of any kind, particularly in the exact sciences.

Definitions

For meanings of all but the most technical terms, the subject specialist should not disdain using the two principal unabridged general dictionaries, namely, *Funk and Wagnalls New Standard Dictionary* and *Webster's New International Dictionary* (Second Edition). The general encyclopedias will also prove helpful on many occasions.

Physics dictionaries.

Deriving obvious advantages from their subject concentration, dictionaries for the field of physics as a whole include the following assorted types:

a. Weld, LeRoy Dougherty. *Glossary of Physics.* New York: McGraw-Hill Book Company, 1937. 255 pp.
"The sole purpose is to give information as to actual usage, and in such form as to be intelligible to students as well as to specialists." As terms are always more easily understood in context, passages containing them are cited. This dictionary is of convenient size for frequent use.

b. Glazebrook, Sir Richard. *A Dictionary of Applied Physics.* London: The Macmillan Company, 1922-1923. 5 vols.

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3. L. W. Taylor, *Physics; The Pioneer Science*, p. 13. Boston: Houghton Mifflin Company, 1941.

This comprehensive encyclopedic dictionary is divided as follows: (Vol. 1) Mechanics, engineering, heat; (Vol. 2) Electricity; (Vol. 3) Meteorology, metrology and measuring apparatus; (Vol. 4) Light, sound, radiology; and (Vol. 5) Aeronautics, metallurgy. Each volume is arranged by broad subject, with cross-references from minor topics. The set is still useful for detailed and well-illustrated expositions of subjects that have not changed too rapidly since its publication.

c. Westphal, Wilhelm H. *Physikalisches Wörterbuch.*[4] Berlin: Springer, 1952. 2 vols. in 1. (833, 795 pp.)

Those reading German will find this a valuable supplement to the English dictionaries at their disposal. The articles embodying definitions are entirely in German, written by eighty subject specialists. Clear Roman typography is employed, rather than Gothic. Appended are: a history of physics; physicists' life-dates; miscellaneous physical tables; and supplementary terms.

Certain subdivisions of applied physics have their own compendia:

a. Cooke, Nelson M., and Markus, John. *Electronics Dictionary; An Illustrated Glossary of over 6,000 Terms used in Radio, Television, Industrial Electronics, Communications, Facsimile, Sound Recordings, etc.* New York: McGraw-Hill Book Company, 1945. 433 pp.

b. Roget, Samuel R. *A Dictionary of Electrical Terms.* (Fourth Edition.) London: Sir Isaac Pitman and Sons, 1941. 432 pp.

This covers "the general science of electricity and magnetism, without proceeding too far into its ramifications in the directions of pure physics and chemistry, etc."[5]

c. Dunlap, Carl H., and Hahn, Enno R. *Electrical and Radio Dictionary.* (Revised Edition.) Chicago: American Technical Society, 1943. 110 pp.

Practical and engineering aspects are stressed.

d. National Research Council. Conference on Nuclear

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4. Supersedes A. Berliner and K. Scheel, *Physikalisches Handwörterbuch.* (Zweite Auflage.) Berlin: Springer, 1932. 1,428 pp.
5. *Op cit.*, p. iv.

Glossary. *A Glossary of Terms in Nuclear Science and Technology.* New York: American Society of Mechanical Engineers, 1950-1953. 9 vols. in 8, as follows: (i) General terms; (ii) Reactor theory; (iii) Reactor engineering; (iv) Chemistry; (v) Chemical engineering; (vi) Biophysics and radiobiology; (vii) Instrumentation; (viii) Isotopes separation; and (ix) Metallurgy.

Further sources of definitions of physics terms are Lindsay's handbook, and the American Standards Association's terminologies. For working definitions one may often rely on certain physics textbooks and handbooks.

Science dictionaries.

For broader coverage of science in general, one has the following references:

a. *Van Nostrand's Scientific Encyclopedia.* (Second Edition.) New York: D. Van Nostrand Company, 1947. 1,600 pp.

This useful large-sized volume has articles of varying length arranged in one alphabet; additional articles may be found for all terms that appear in boldface type. In this revision much new material has been added.

b. *Chambers's Technical Dictionary,* edited by C. F. Tweney and L. E. C. Hughes. (Revised Edition.) New York: The Macmillan Company, 1948. 976 pp.

Over 50,000 terms of science and technology are defined, including many new definitions throughout the text and in a twenty-five page supplement.

c. Beadnell, C. M. *Dictionary of Scientific Terms.* (Second Edition.) London: Watts and Company, 1942. 232 pp.; 13 pp. (Supp.)

Words likely to be encountered by the layman in scientific publications are defined.

Abbreviations and symbols.

The following provide comprehensive collections of miscellaneous abbreviations:

a. Zimmerman, O. T., and Lavine, Irvin. *Scientific and Technical Abbreviations, Signs and Symbols.* (Second Edi-

tion.) Dover, N. H.: Industrial Research Service, 1949. 541 pp.

b. Shankle, George E. *Current Abbreviations.* New York: The H. W. Wilson Company, 1945. 207 pp.

Physics symbols[6] and a discussion of the principles of letter symbol standardization appear in:

"American Standard Letter Symbols for Physics." Final Report (No. 4) of the Committee on Letter Symbols. *American Journal of Physics,* 16: 164-179, March 1948.

These symbols also appear in the Chemical Rubber Publishing Company's handbook, and in a separate *ASA Standard* previously mentioned.

Other useful discussions are:

a. International Union of Pure and Applied Physics. *Reports on Symbols, Units and Nomenclature approved by the General Assembly of the Union at its Meeting in London on 5th October, 1934.* London: The Physical Society, 1935. 40 pp.

Partial contents are: Standard thermal unit; Electrical and magnetic units; Certain thermodynamic symbols.

b. Joint Committee of the Chemical Society, the Faraday Society, and the Physical Society. *Report on Symbols for Thermodynamical and Physico-Chemical Quantities and Conventions Relating to Their Use.* London: The Committee, 1937. 16 pp.

Translations

A recently established Scientific Translations Center in the Science Division, Library of Congress, collects translated technical material from many sources in order that our scientists may keep informed of foreign developments. Major initial emphasis will be on translations from Russian scientific journals. Photocopies may be purchased of items listed monthly, except those available by direct purchase from translating services.

For news of translated books one may consult the new series of volumes of *Index Translationum,* an international bibliography of translations that resumed publication under UNESCO

6. *See also* D. Roller, "A Proposed Procedure for Selecting and Using Symbols for Physical Units." *American Journal of Physics,* 21: 293-296, April 1953.

auspices in 1949. It lists translations published in the languages of many countries (including the United States), under subheadings such as "Natural and Exact Sciences."

When language equivalents rather than definitions of words are sought, one turns to bi-lingual or multi-lingual dictionaries.

General foreign dictionaries.

A few well-known examples follow:

a. Mansion, J. E. *Heath's Standard French and English Dictionary.* Boston: D. C. Heath and Company, 1934-1939.[7] 2 vols.

b. Breul, Karl H. *Heath's New German and English Dictionary,* revised and enlarged by J. H. Lepper and R. Kottenhahn. Boston: D. C. Heath and Company, 1939. 2 pts. in 1 (813, 687 pp.)

c. Klatt, Edmund. *Langenscheidts Taschenwörterbuch der Englischen und Deutschen Sprache.* (First American Edition.) New York: Dover Publications, 1944. 2 vols. in 1.

d. Cuyás, Arturo. *Appleton's New English-Spanish and Spanish-English Dictionary,* revised and enlarged by A. Llano. (Third Edition.) New York: D. Appleton-Century Company, 1940. 2 vols. in 1 (596, 539 pp.)

Technical foreign dictionaries.

An extensive bibliography has been compiled under United Nations auspices:

Holmstrom, J. E. *Bibliography of Interlingual Scientific and Technical Dictionaries.* Paris: United Nations Educational, Scientific and Cultural Organization, 1951. 220 pp.

Depending on typography and comprehensiveness, such dictionaries vary widely from pocket size to several large volumes. Examples of small bi-lingual dictionaries are:

a. De Vries, Louis. *German-English Science Dictionary for Students in Chemistry, Physics, Biology, Agriculture and Related Sciences.* (Second Edition.) New York: McGraw-Hill Book Company, 1946. 558 pp.

b. De Vries, Louis. *German-English Technical and Engi-*

7. Reprinted 1947-1948 with corrections.

neering Dictionary. New York: McGraw-Hill Book Company, 1950. 928 pp.

c. Patterson, Austin M. *A German-English Dictionary for Chemists.* (Third Edition.) New York: John Wiley and Sons, 1950. 541 pp.

d. Regen, Bernard R., and Regen, Richard R. *German-English Dictionary for Electronics Engineers and Physicists.* Ann Arbor, Mich.: J. W. Edwards, 1946. 358 pp.

e. De Vries, Louis. *French-English Science Dictionary for Students in Agriculture, Biology, and Physical Sciences.* (Second Edition.) New York: McGraw-Hill Book Company, 1951. 596 pp.

f. Patterson, Austin M. *A French-English Dictionary for Chemists.* New York: John Wiley and Sons, 1921. 384 pp.

g. Guinle, R. L. *A Modern Spanish-English and English-Spanish Technical and Engineering Dictionary.* New York: E. P. Dutton and Company, 1938. 311 pp.

h. Callaham, L. I. *Russian-English Technical and Chemical Dictionary.* New York: John Wiley and Sons, 1947. 794 pp.

Larger bi-lingual dictionaries more useful because of their comprehensiveness, are:

a. Webel, A. *A German-English Technical and Scientific Dictionary.* (Second Edition.) New York: E. P. Dutton and Company, 1937. 887 pp.

b. Kettridge, Julius O. *French-English and English-French Dictionary of Technical Terms and Phrases.* London: G. Routledge and Sons, 1925. 2 vols.

Multi-lingual lexicons enable one to work among several languages simultaneously:

a. *Hoyer-Kreuter Technologisches Wörterbuch,* herausgegeben von Alfred Schlomann. (Sechste Auflage.) Berlin: Springer, 1932. 3 vols.
Vol. 1: Deutsch-English-Französisch; Vol. 2: English-German-French; Vol. 3: Francais-Allemand-Anglais.

b. Newmark, Maxim. *Dictionary of Science and Technology in English-French-German-Spanish.* New York: Philosophical Library, 1943. 386 pp.

c. Cornubert, R. *Dictionnaire Anglais-Français-Allemand*

de Mots et Locutions Intéressant la Physique et la Chimie. Paris: Dunod, 1922. 297 pp.
English, French and German words are aligned in three parallel columns, with the bold-face terms in each column forming an alphabetical finding list for that column.

A "reading-knowledge" of a foreign scientific language, especially German, may be obtained by using a standard grammar with books like the following:

a. De Vries, Louis. *Guide to Scientific German.* New York: Rinehart and Company, 1947. 54 pp.
Grammar résumés are followed by illustrative passages. "In no other workbook will an instructor find such a variety of troublesome constructions presented in so few pages."

b. Barker, M. L. *Basic German for Science Students.* (Third Edition.) Cambridge, England: W. Heffer and Sons, 1937. 186 pp.
Economy of effort is stressed by presenting minimum essentials of grammar, and by emphasizing words which are of most frequent occurrence in German writings. Parallel translations are provided.

c. Calthrop, John E. *A German Physics Reader.* London: William Heinemann, 1943. 83 pp.
Passages on the history of physics with parallel translations opposite are followed by exercises for translation.

d. Baravalle, Hermann von. *Physik; Wärmelehre, Magnetismus, Elektrizität,* edited by S. H. Muller. Boston: D. C. Heath and Company, 1946. 50 pp.
Terms appearing in the German text are defined on the page opposite.

e. Sängewald, Rudolf. *A Contemporary German Science Reader,* edited by Louis De Vries. New York: Rinehart and Company, 1948. 258 pp.

f. Curts, Paul H. *Readings in Scientific and Technical German.* New York: Henry Holt and Company, 1935. 284; 123 pp.
The articles comprise an outline of science, and may be used with the author's *Basic German* (Third Edition; Prentice-Hall, 1952; 129 pp.)

g. Alberse, James D. *Chemical French Reader.* Boston: D. C. Heath and Company, 1940. 117 pp.
The passages on x-rays, radioactivity, etc., are of physics interest.

h. Perry, James W. *Scientific Russian.* New York: Interscience Publishers, Inc., 1950. 816 pp.

Summary

Roller's booklet on terminology provides a useful résumé of the peculiarities of scientific words, and a guide to their meaning and correct use. Definitions may be found in general or specialized dictionaries, including those of encyclopedic type. Glazebrook's compilation stands out among the latter, although outdated in some areas. For translating, there is a choice between general foreign-language dictionaries and those of scientific nature. Combined use of both types is a common compromise after one has mastered language difficulties via grammar and chrestomathy.

CHAPTER IX

ADDITIONAL APPROACHES
Miscellaneous Aspects

Before proceeding with a topical treatment of physics based on subject content, a remaining group of aspects will be discussed, viz., presentational, philosophical, and practical.

1—Presentational

As previously indicated, outstanding scientists are usually master expositors whose firm grasp of their subject enables them to enlighten others. All physics teachers and students should strive for this clarity of expression, both oral and written. Furthermore, good exposition is enriched by teaching aids, such as demonstrations, audio-visual materials, etc.

Lectures.

Audience interest may be aroused and sustained by good speaking techniques[1] and by the visual appeal of demonstrations, such as those described in:

Sutton, Richard M. *Demonstration Experiments in Physics.* New York: McGraw-Hill Book Company, 1938. 545 pp. General techniques are discussed (pp. 1-14), and further sources of experiments are listed (pp. 509-510).

A widely used German compilation is:

Weinhold, Adolf F. *Physikalische Demonstrationen,* bearbeitet von L. Weinhold and M. Günther. (7. Auflage.) Leipzig: J. A. Barth, 1931. 740 pp.

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1. See K. K. Darrow, "How to Address the American Physical Society." *Physics Today,* 4 (No. 2): 4-8, February 1951; also S. M. Tucker, *Public Speaking for Technical Men.* New York: McGraw-Hill Book Company, 1939. 397 pp.

Simple equipment[2] is featured in experiments selected from the English *School Science Review:*

Adlam, G. H. J., editor. *The Science Masters' Book.* Series 1-2. London: John Murray, 1931-1936. 256 pp; 273 pp. Each series is in two parts: Part I, Physics; Part II, Chemistry and biology.

Optics has its own collection:

Johnson, B. K. *Lecture Experiments in Optics.* London: Edward Arnold and Company, 1930. 112 pp.

The most time-honored lecture series has been held annually since 1826 at the Royal Institution of London, as described in a recent article.[3] The lectures were designed for "a juvenile auditory" but all ages gathered to enjoy the brilliant expositions and spectacular demonstrations. Abbreviated references to some of the books based on the series follow:

Andrade, E. N. *Engines.* Bell, 1928. 267 pp.

Bragg, W. H. *Concerning Nature of Things.* Bell, 1925. 232 pp.

Bragg, W. H. *Universe of Light.* Bell, 1933. 283 pp.

Bragg, W. H. *World of Sound.* Bell, 1920. 196 pp.

Bragg, W. L. *Electricity.* Bell, 1936. 286 pp.

Faraday, M. *Various Forces of Matter.* (3d ed.) Griffin, 1861. 179 pp.

Fleming, J. A. *Waves and Ripples.* (Rev. issue) Sheldon, 1923. 299 pp.

Wood, A. *Sound Waves.* Blackie, 1930. 152 pp.

Demonstrations may also be of display type, often operable by the visitor[4] and accompanied by descriptive lectures, as in these instances:

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2. Also employed in: K. M. Swezey, *After Dinner Science.* New York: McGraw-Hill Book Company, 1948. 182 pp.; and in I. M. Freeman, *Invitation to Experiment.* New York: E. P. Dutton and Company, 1940. 238 pp.
3. T. Martin, "Christmas Lectures at the Royal Institution." *Physics Today,* 1 (No. 3): 10-15, July 1948. (For paintings of lectures, see *American Journal of Physics,* 8: 387-390, December 1940.)
4. See R. P. Shaw, "The Progressive Exhibit Method." *American Physics Teacher,* 7: 165-172, June 1939. (New York Museum of Science and Industry.)

a. Lemon, Harvey B., and Marshall, Fitz-Hugh. *The Demonstration Laboratory of Physics at the University of Chicago.* Chicago: University of Chicago Press, 1939. 127 pp.
This and similar museum projects are discussed as educational tools.

b. London. Board of Education. Science Museum. *Very Low Temperatures,* edited by T. C. Crawhall. London: His Majesty's Stationery Office, 1936-1937. 3 "books."
Book I summarizes the physical principles; Book II describes the exhibits (in the Science Museum, March-June, 1936); Book III presents the symposium.

Background materials are presented in the books by J. S. Richardson, E. D. Heiss, M. N. Woodring, *et al.* Quotation compendia are listed on pages 365-366 of Winchell.

Writings.

Roller's interesting article[5] may be supplemented by:

a. Flesch, Rudolf F. *The Art of Readable Writing.* New York: Harper and Brothers, 1949. 237 pp.

b. Crouch, W. G., and Zetler, Robert L. *A Guide to Technical Writing.* New York: Ronald Press Company, 1948. 401 pp.

c. Trelease, Sam F. *The Scientific Paper; How to Prepare It; How to Write It.*[6] Baltimore: Williams and Wilkins Company, 1947. 152 pp.

d. Nelson, J. Raleigh. *Writing the Technical Report.* (Third Edition.) New York: McGraw-Hill Book Company, 1952. 356 pp.

e. Gloag, John. *How to Write Technical Books.* London: George Allen and Unwin, Ltd., 1950. 159 pp.

When a book is being prepared with a particular publisher in mind, the author should observe that firm's accepted style, usually outlined in its own manual. Suggestions for style of articles may be found on the covers of certain journals, while an important group of physics periodicals has its own guide:

5. D. Roller, "Technical Writing and Editing." *American Journal of Physics,* 13: 99-105, April 1945.

6. A revision of his earlier pamphlet *Preparation of Scientific and Technical Papers.*

American Institute of Physics. *Style Manual for Guidance in the Preparation of Papers for Journals Published by the American Institute of Physics.* New York: The Institute, 1951. 28 pp.

The contents comprise: Short history of a manuscript; Preparation of a scientific paper; Preparation of the abstract; Preparation of figures; General style; Presentation of mathematical expressions; Special characters and signs available.

A good general style manual is:

Mawson, C. O. S. *Style-book for Writers and Editors.* New York: Thomas Y. Crowell Company, 1926. 213 pp.

The basis of correct style is stressed. "The style-books of the foremost publishers in the United States and Great Britain have been critically examined, in order that the most approved usages might be followed."

Other style manuals are listed, together with comments on prospective publications, by Scherr.[7] *See also* A. C. R. L.[8] Monograph No. 8 (1953): *Bibliographical Style Manuals; A Guide to their Use in Documentation and Research,* by Mary R. Kinney.

Literary aspects of technical literature may be derived from:

a. Law, Frederick H., editor. *Science in Literature; A Collection of Literary Scientific Essays.* New York: Harper and Brothers, 1929. 364 pp.

Prepared for high school use, this emphasizes the spirit and style of excerpted writings, such as Madame Curie's, "The Discovery of Radium." The author states (p. xvi):

> . . . The purpose of this book is not at all the presenting of facts, or the explanation of theories, but wholly the literary power, the driving force, the uplifting inspiration, of the words of scientific workers.

b. Drachman, Julian M. *Studies in the Literature of Natural Science.* New York: The Macmillan Company, 1930. 487 pp.

Attractiveness of presentation does not depend upon artificial embellishment, according to Tripp, who states:

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7. J. M. Scherr, "Authorship Without Tears; A Guide to Authors' Handbooks and Publishers' Style Manuals." *Bulletin of Bibliography,* 18: 225-227, May-August 1946.
8. Association of College and Reference Libraries.

> It is the first duty of the monograph writer to estimate the value, either actual or potential, of recent work upon the subject of which he writes: he must pick out the plums to save others from the indigestion that follows eating the whole pie. Further, in addition to being accurate, his work must be presented in a form both assimilable and attractive; in other words, he must show that lucid exposition can be achieved by the use of few words, if they are rightly chosen, and that attractive presentation is attained rather by clear thinking than by superficial display.[9]

Finally, attention should be paid to the composition of the whole printed page, for "the visual task of reading is created by those who plan printed material," as expounded in:

Luckiesh, Matthew, and Moss, Frank K. *Reading as a Visual Task.* New York: D. Van Nostrand Company, 1942. 428 pp.

Pictorial devices.

Various estimates have been ventured concerning the number of printed words that one good illustration equals. Scientific illustration from several viewpoints is described in:

a. Ridgway, John L. *Scientific Illustration.* Stanford University, Cal.: At the University Press, 1938. 173 pp.
This outlines "effective methods of preparation and the proper fitting, assembling, and display of illustrations designed for scientific publications."

b. Clarke, Carl D. *Illustration; Its Technique and Application to the Sciences.* Baltimore: The John D. Lucas Company, 1940. 386 pp.
Examples are drawn chiefly from chemistry and physiology.

c. Hoelscher, Randolph P., *et al. Industrial Production Illustration for Students, Draftsmen and Illustrators.* (Second Edition.) New York: McGraw-Hill Book Company, 1946. 243 pp.

Drafting in conformity with U. S. Patent Office requirements is shown by:

Radzinsky, Harry. *Making Patent Drawings.* New York: The Macmillan Company, 1945. 96 pp.

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9. E. H. Tripp in preface to J. A. Radley and J. Grant, *Fluorescence Analysis in Ultra-violet Light*, pp. v-vi. (Third Edition.) London: Chapman and Hall, Ltd., 1939.

Physics graphs and diagrams constitute an unusual German compilation designed to accompany a textbook:

Auerbach, Felix. *Physik in Graphischen Darstellungen.* (Zweite Auflage.) Leipzig: B. G. Teubner, 1925. 257, 29 pp. There are 1557 pictorial representations of physical entities, such as hysteresis loops, Van der Waals constant plots, flame pictures, etc.

Portraits of physicists are included in a superb portfolio:

Crew, Henry. *Portraits of Famous Physicists.* New York: Scripta Mathematica, Yeshiva College, 1942. 12 folders. Brief biographical sketches accompany the portraits of Ampère, Clausius, Faraday, Fresnel, Galileo, Gibbs, Hertz, Huygens, Joule, Maxwell, Newton, Rowland.

Similar portfolios that include some physicists are as follows:

Journal of Chemical Education. Distinguished Chemists. Series A, B. C. Easton, Pa.: Mack Printing Company, 1935-1936. 3 folders.

Many Nobel prize-winners' portraits appear in MacCallum. *Biographical Memoirs* (National Academy of Sciences), and *Obituary Notices of Fellows of the Royal Society of London,* both feature portraits.

Other sources of portraits are the general and biographical encyclopedias, histories, biographies, and the following index:

A. L. A. Portrait Index, edited by W. C. Lane and N. E. Browne. Washington, D. C.: Library of Congress, 1906. 1600 pp.

"Reproduction of Prints, Drawings and Paintings of Interest in the History of Physics" have been appearing in the *American Journal of Physics* and its predecessor *(American Physics Teacher)* from 1938 to 1949, and resuming in the September 1952 issue. They may be located under name of contributor, E. C. Watson, in the annual author indexes.

Schaeffer[10] finds similar historic interest in certain postage-stamp designs.

Audio-visual materials, such as motion-pictures,[11] slides, film-

10. H. F. Schaeffer, "Philately for Physicists." *American Physics Teacher,* 6: 21-24, February 1938.

11. See C. J. Lapp, "The Effectiveness of a Sound Motion Picture in College Physics." *American Physics Teacher,* 7: 224-230, August 1939.

strips, recordings, etc., are increasingly gaining prominence as educational tools. Typical of numerous descriptive manuals is:

Haas, Kenneth B., and Packer, Harry Q. *Preparation and Use of Audio-visual Aids.* (Revised and Enlarged Edition.) New York: Prentice-Hall, Inc., 1950. 329 pp.

Virtually all current 16-mm educational films are listed in the *Educational Film Guide,* published quarterly with annual cumulations by the H. W. Wilson Company. Its two parts are: (1) An alphabetic title and subject index; (2) A classified and annotated subject list.

Filmstrips are indexed in another Wilson service, *Filmstrip Guide,* appearing quarterly and cumulating annually. For record of filmstrips prior to 1947, see:

Falconer, Vera M. *Filmstrips; A Descriptive Index and Users' Guide.* New York: McGraw-Hill Book Company, 1948. 572 pp.

Other sources of physics films include:

a. *Index of Training Films,* prepared by the editors of Business Screen Magazine. (Third Edition.) Chicago: Business Screen Magazine, 1951. 85 pp.
Topics of physics interest are: Electronics; Engineering; Optics; Physics.

b. Weber, Robert L. "Films Selected for First-Year College Physics." *American Journal of Physics,* 17: 408-412, October 1949.

c. Notarius, Nanette, and Larson, Allan S. *The Handbook of Free Films.* New York: Allanan Associates, Inc., 1952. 237 pp.
(See the "Technical and Training" special-interest index, pp. 187-191.)

Various engineering firms, e.g., General Electric Company, produce and distribute free films incorporating maximum information and minimum advertising.

2—Philosophical

Although there is a borderland between physics and philosophy, it is not as wide and uncharted as the casual observer

might suppose. The following statements indicate narrowing of the gap:

> In a still broader sense physics, in the hands of several distinguished scholars, is showing a tendency to justify its original title of "natural philosophy." Certainly it is true, as it has been in the past, that the discoveries of science, however abstract they may be, have a profound bearing upon our thought. More and more do the findings of modern physics, as for example relativity and atomic theory, bring to philosophy contributions whose importance can hardly be over-estimated.[12]

"Physics and philosophy thus cooperate in giving us a complete knowledge of the universe."[13]

Philosophy of science.

A thorough understanding of physics methodology and concepts should precede attempts at philosophical reasoning. In addition to several books previously cited at the beginning of Chapter V, see the following:

a. Conant, James B. *Science and Common Sense.* New Haven, Conn.: Yale University Press, 1951. 271 pp.

The author interprets science for the layman, less pedagogically than in his earlier *On Understanding Science.*

b. Watson, W. H. *On Understanding Physics.* Cambridge, England: At the University Press, 1938. 146 pp.

c. Bridgman, Percy W. *The Logic of Modern Physics.* New York: The Macmillan Company, 1927. 228 pp.

The author states (p. x):

> It is the attempt of this essay to give a more or less inclusive critique of all physics. Our problem is the double one of understanding what we are trying to do and what our ideals should be in physics, and of understanding the nature of the structure of physics as it now exists. These two ends are together furthered by an analysis of the fundamental concepts of physics; an understanding of the concepts we now have discloses the present structure of physics, and a realization of what the concepts should be involves the ideals of physics.

d. Bridgman, Percy W. *The Nature of Physical Theory.* Princeton, N. J.: Princeton University Press, 1936. 138 pp.

A few of the many philosophical treatments may be cited:

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12. A. B. Crawford and S. H. Clement, *The Choice of an Occupation,* p. 159. New Haven, Conn.: Yale University Press, 1932.
13. O. A. Grosselin, "The Relation of Physics to Philosophy." *American Journal of Physics,* 9: 285-290, October 1941.

a. Planck, Max. *The Philosophy of Physics.* New York: W. W. Norton and Company, 1936. 128 pp.
Contents are: Physics and world philosophy; Causality in nature; Scientific ideas: their origin and effects; Science and faith.

b. Jeans, Sir James H. *Physics and Philosophy.* Cambridge, England: At the University Press, 1943. 222 pp.

c. Frank, Philipp. *Modern Science and its Philosophy.* Cambridge, Mass.: Harvard University Press, 1949. 324 pp.

d. Smith, Vincent E. *Philosophical Physics.* New York: Harper and Brothers, 1950. 472 pp.

An interesting compilation is available:

Wiener, Philip P. *Readings in Philosophy of Science; Introduction to the Foundations and Cultural Aspects of the Sciences.* New York: Charles Scribner's Sons, 1953. 645 pp.

Psychological aspects are reflected in:

Stevens, Blamey. *The Psychology of Physics.* Manchester, England: Sherratt and Hughes, 1939. 282 pp.
The author develops his perceptual theory, maintaining that the laws of physics are subjective rather than objective. "Perceptual theory thus supplies us with a fundamental system to which all phenomena may be referred. Without such perceptual basis physics is a collection of detached laws."

Social implications of science.

Selected books that reveal appreciation of science's contribution to civilization, and, more recently, apprehension concerning its destructive potentialities, follow:

a. Clark, G. N. *Science and Social Welfare in the Age of Newton.* London: Oxford University Press, 1937. 159 pp.

b. Mumford, Lewis. *Technics and Civilization.* New York: Harcourt, Brace and Company, 1934. 495 pp.

c. Cohen, I. Bernard. *Science Servant of Man.* Boston: Little, Brown and Company, 1948. 362 pp.

d. Bridgman, Percy W. *Reflections*[14] *of a Physicist.* New York: Philosophical Library, 1950. 392 pp.

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14. Concerning science and society, as well as operationalism: "the meaning of any concept is to be sought in the operations, whether physical or mental, which are performed in making application of that concept."

e. Burchard, John E., editor. *Mid-century: The Social Implications of Scientific Progress.* New York: John Wiley and Sons, 1950. 549 pp.
Addresses and supplementary material in connection with an inaugural convocation at the Massachusetts Institute of Technology in 1949 are presented under headings such as: The state of science; Men against nature; Men against men; The store of the future.

See also the quarterly UNESCO journal, *Impact of Science on Society,* and the U. N. *International Bibliography of Atomic Energy,* Vol. 1.

3—Practical

Practical aspects of physics include its applications in industry, its role in the home, and its choice as a career by the embryo scientist.

Industrial applications.

That "Physics is the foundation upon which most lines of engineering are built"[15] is amply demonstrated by the following:

a. *Physics in Industry.*[16] New York: American Institute of Physics, 1937. 290 pp.
This compilation of papers by K. T. Compton, E. C. Sullivan, Zay Jeffries, *et al.,* marked the Institute's fifth anniversary. Topics connected with the glass, metal, petroleum, building, electrical and other industries were treated, followed by a discussion of the training of physicists from educator's and employer's viewpoints. Compton points out (p. x):

> Not all who are physicists call themselves by that name and therein lies one reason why the average citizen has little comprehension of what physics really is. There has been a very interesting historic trend in physics by which great branches of its specialized interests have been appropriated by special groups of physicists who call themselves engineers just as soon as a systematic method of applying phys-

15. J. G. McGuire and H. W. Barlow, *An Introduction to the Engineering Profession,* p. 165. (Second Edition.) Cambridge, Mass.: Addison-Wesley Press, 1951.
16. See also C. G. Suits, "Physics in Industry." *American Journal of Physics,* 18: 55-61, February 1950.

ical principles to advantageous ends has been developed in a specialized field.

b. Institute of Physics, London. *Physics in Industry.* London: The Institute, 1923 to date.

These pamphlets appear irregularly and present lectures by representatives from industry and the universities. One entitled "Magnetism" (1938) has an interesting comment by W. L. Bragg (p. vi):

> One cannot guarantee that the pure scientist, when made acquainted with the problems with which industry is faced, will immediately have a "brain wave" which will enable him to suggest a solution. One can say, however that unless he has some knowledge of these problems the chances of his being of assistance are very remote. By helping each other to grasp the main essential problems, we create the conditions in which inspiration is most likely to come.

What physics has been doing for industry and the fine arts is also interestingly recounted in:

Richardson, Edward G. *Physical Science in Art and Industry.* (Second Edition.) London: The English Universities Press, 1946. 299 pp.

More specialized surveys are:

a. Bosworth, R. C. L. *Physics in Chemical Industry.* London: The Macmillan Company, 1950. 928 pp.

b. Starling, Sydney G. *Electricity in the Service of Man,* revised by H. J. Gray. (Second Edition.) New York: Longmans, Green and Company, 1949. 255 pp.

c. *Applied Physics: Electronics; Optics; Metallurgy.* Boston: Little, Brown and Company, 1948. 456 pp.

This unit of the "Science in World War II" series reviews accomplishments of the U. S. Office of Scientific Research and Development, whereby our defense has been linked with scientific potential.

Atomic energy developments have made it clear that, "No engineer can now say with any assurance what aspects, if any, of physical or chemical research lie outside his sphere. Never before has it been truer than now that the physics of to-day is the engineering of to-morrow."[17]

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17. T. W. Chalmers, *Historic Researches,* p. 2. New York: Charles Scribner's Sons, 1952.

Physics even reaches out to trap the criminal, as described in:

O'Hara, Charles E., and Osterburg, James W. *An Introduction to Criminalistics; The Application of the Physical Sciences to the Detection of Crime.* New York: The Macmillan Company, 1949. 705 pp.

Of particular physics interest are discussions of the use of ultraviolet, infrared, and X-rays; photomicrography; measurement of distances, speed or force in the examination of skid marks, shattered glass, etc.

See also the final sections of the Topical Approach discussions, e.g., Applied Mechanics, Applied Thermodynamics, etc.

Household applications.

The following textbooks, addressed primarily to home economics students, link physics principles with everyday experiences:

a. Whitman, Walter G. *Household Physics.* (Third Edition.) New York: John Wiley and Sons, 1939. 436 pp.

The author asserts (p. v):

> So rapid is progress in practical science that the average home of today has much equipment that was either unknown or was in the early stages of development ten years ago. Every year man in a progressive community becomes more and more dependent on devices of his own creation which make use of the principles of physics. . . . There is no question but that greater knowledge of the underlying principles and an understanding of the operation of many of these household devices will increase their efficiency and cut down the repair bills. It is also a matter of satisfaction to many to understand "how it works."

b. Avery, Madalyn. *Household Physics.* (Revised Edition.) New York: The Macmillan Company, 1946. 470 pp.

c. Osborn, Frederick A. *Physics of the Home.* (Third Edition.) New York: McGraw-Hill Book Company, 1935. 441 pp.

d. Lynde, Carleton J. *Everyday Physics.* New York: The Macmillan Company, 1936. 577 pp.

Physics as a vocation.

The National Roster of Scientific and Specialized Personnel has prepared an excellent occupational outline of the profession of physics, listing its major branches as areas of specialization:

"What is a Physicist?" *Review of Scientific Instruments,* 15: 54-56, February 1944.

Whether he is adapted to practice physics as a profession, and how he may obtain a position in the field, are two extremely practical problems confronting the student contemplating a career. Both aspects are delineated in recent summaries, from American and English viewpoints, respectively:

a. Smith, Alpheus W. *Careers in Physics.* Columbus, Ohio: Long's College Book Company, 1951. 272 pp.

Full contents are: Physics as a profession; Educational preparation and goals; Supply and demand; Careers in education; Industrial physicists; Power and progress; Illumination and vision; Communication; Transportation and mobility; Materials and products for better living; Photography and its uses; Instrumentation; Careers in civil federal research agencies; Careers in military research agencies; Research institutes and foundations; Classical physics; Modern physics; Atmospheric physics and meteorology; Food and health physics; Borderland fields for specialization; Industrial research laboratories; Bibliography.

b. Clarke, Norman. *Physics as a Career.* London: Institute of Physics, 1952. 70 pp.

This performs a similar function for British avenues of training and employment.

c. Pollack, Philip. *Careers in Science.* New York: E. P. Dutton and Company, 1945. 222 pp.

Of interest to prospective physicists are Chapter V and VI, and supplementary pages 180-199.

Briefer résumés appear in:

a. American Institute of Physics. *Physics as a Career.* New York: The Institute, 1952. 17 pp.

b. Institute for Research. *Career as a Physicist.* Chicago: The Institute, 1946. 20 pp. (Its *Careers* series, Research No. 143.)

c. Crawford, Albert B., and Clement, Stuart H. *The Choice of an Occupation,* pp. 156-160. New Haven, Conn.: Yale University Press, 1932.

d. Stewart, George W. "Physics as a Career." *Science,* n.s. 58: 275-278, October 12, 1923.

This has also been reprinted by the National Research Council

as one of the "career bulletins" comprising its collection, "Opportunities for a Career in Scientific Research," 1927.

Sidelights on scientific work for official agencies are given in:

Attitudes of Scientists and Engineers about Their Government Employment. Vol. 1. Syracuse, N. Y.: Syracuse University, 1950. 223 pp.

This was compiled by the Maxwell Graduate School of Citizenship and Public Affairs for the Office of Naval Research.

See also several articles on the physicist in the government service in *American Physics Teacher,* 7: 148-163, June 1939.

Manuals for special fields include:

a. Hartzell, Karl D. *Opportunities in Atomic Energy.* New York: Grosset and Dunlap, 1951. 143 pp.

After sketching the atomic energy program, the author discusses personnel policies, training, qualifications, salaries, types of work, etc.

b. Kamen, Ira, and Dorf, Richard H. *TV and Electronics as a Career.* New York: John F. Rider Publisher, Inc., 1951. 326 pp.

Engineering and commercial phases are emphasized.

Professional placement announcements appear among the pages of various physics periodicals, notably *Physics Today, Journal of Applied Physics,* etc.

Two employment surveys were recently made:

a. National Scientific Register. *Manpower Resources in Physics, 1951.* Washington, D. C.: Government Printing Office, 1952. 46 pp. (Scientific Manpower Series No. 3.)

Data on the training, specialization, age distribution, and employment of 6600 physicists are given.[18]

b. *Employment, Education and Earnings of American Men of Science.* Washington, D. C.: Government Printing Office, 1951. 48 pp. (U. S. Bureau of Labor Statistics Bulletin No. 1027.)

This covers 42,000 scientists from the 1949 edition of *American Men of Science.*

Scholarships and graduate fellowships are listed in:

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18. Related discussions appear in *Physics Today,* 5 (No. 11): 4-7, November 1952; and *ibid,* 6 (No. 2): 14-16, February 1953.

a. Wilkins, Theresa B. *Scholarships and Fellowships Available at Institutions of Higher Education.* (Third Edition.) Washington, D. C.: Government Printing Office, 1951. 248 pp. (U. S. Office of Education Bulletin 1951, No. 16.)
Pertinent headings include: Physics, Atomic energy, Natural sciences, Science.

b. Feingold, S. Norman. *Scholarships, Fellowships and Loans.* Boston: Bellman Publishing Company, 1949-1951. 2 vols.

c. *Rockefeller Foundation Directory of Fellowship Awards, 1917-1950.* New York: The Foundation, 1951. 286 pp.

See also Waterman's article.[19] The National Science Foundation awards research grants and fellowships, as statistically summarized in its report *Federal Funds for Scientific Research and Development at Nonprofit Institutions, 1950-51 and 1951-52* (available from U. S. Government Printing Office).

Factors most important in interesting undergraduates in science as a vocation are investigated in:

Knapp, Robert H., and Goodrich, H. B. *Origins of American Scientists.* Chicago: University of Chicago Press, 1952. 450 pp.
This statistical study of the "scientist-production efficiency of some 490 universities and colleges" may be used with Visher's book, and two articles by Haberly.[20]

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19. A. T. Waterman, "The National Science Foundation—Its Organization and Purposes." *American Journal of Physics*, 20: 73-77, February 1952.
20. A. A. Haberly, "Who are the Physicists?" *Physics Today*, 6 (No. 8): 13-15, August 1953; and his "How They Became Physicists." *ibid*, 6 (No. 9): 14-16, September 1953.

CHAPTER X

TOPICAL APPROACH

1—General

General textbooks.

Examination of the numerous textbooks of elementary physics on library shelves reveals essential similarity of content. Format has improved greatly during recent years, making physics study more fascinating. Each author, of course, believes his book excels in arrangement, subject content, and clarity of expression. In reality, many books serve the purposes of other teachers[1] almost equally well, leading to widespread adoption and economy of effort. As Lemon declares:

> Of the writing of textbooks of physics there seems to be no end. This will probably continue to be the case as long as the science develops—as long as the detailed requirements of technical training become more and more extended—and as long as there are teachers of physics who are interested in the efficient pursuit of this aspect of their vocation.[2]

A representative group of general textbooks follows:

a. Duff, A. W., *et al. Physics.* (Eighth Edition.) Philadelphia: The Blakiston Company, 1937. 715 pp.

b. Perkins, Henry A. *College Physics.* (Third Edition.) New York: Prentice-Hall, Inc., 1948. 786 pp.

c. Sears, Francis W., and Zemansky, Mark W. *College Physics.*[3] (Second Edition.) Cambridge, Mass.: Addison-Wesley Press, 1952. 2 vols.

d. Semat, Henry. *Fundamentals of Physics.* (Revised Edition.) New York: Rinehart and Company, 1951. 849 pp.

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1. Cf. J. W. McGrath, "Instructor Opinion on Characteristics of a Good General Physics Textbook." *American Journal of Physics,* 13: 309-314, October 1945.
2. H. B. Lemon and M. Ference, *Analytical Experimental Physics,* p. v. (Revised Edition.) Chicago: University of Chicago Press, 1946.
3. To be distinguished from their *University Physics* which introduces calculus, as does the three-volume set *Principles of Physics* by Sears alone.

e. Smith, Alpheus W. *The Elements of Physics.* (Fifth Edition.) New York: McGraw-Hill Book Company, 1948. 745 pp.

f. Stewart, Oscar M., and Gingrich, Newell S. *Physics; A Textbook for Colleges.* (Fifth Edition.) Boston: Ginn and Company, 1950. 726 pp.

Many books reveal definite slants with respect to intended use or author's outlook. For example, one in which historical considerations prevail is:

Taylor, Lloyd W. *Physics; The Pioneer Science.* Boston: Houghton Mifflin Company, 1941. 847, 44 pp.

For engineering students, we have:

a. Hausmann, Erich, and Slack, E. P. *Physics.* (Third Edition.) New York: D. Van Nostrand Company, 1948. 793 pp.

b. Duncan, John, and Starling, S. G. *A Text Book of Physics for Students of Science and Engineering.* (Second Edition.) London: The Macmillan Company, 1948. 1063 pp.

Adapted to science survey courses are:

a. Semat, Henry. *Physics in the Modern World.* New York: Rinehart and Company, 1949. 434 pp.

b. Lemon, Harvey B. *From Galileo to the Nuclear Age.* (Revised Edition of *From Galileo to Cosmic Rays.*) Chicago: University of Chicago Press, 1946. 451 pp.

Unifying treatments of physical properties include:

a. Newman, F. H., and Searle, V. H. L. *The General Properties of Matter.* (Fourth Edition.) New York: Longmans, Green and Company, 1948. 431 pp.

b. Champion, Frank C., and Davy, N. *Properties of Matter.* London: Blackie and Son, 1936. 296 pp.

Finally, for modern as opposed to classical physics there are such authoritative textbooks as:

a. Richtmyer, Floyd K., and Kennard, E. H. *Introduction to Modern Physics.* (Fourth Edition.) New York: McGraw-Hill Book Company, 1947. 759 pp.

b. Jauncey, George E. M. *Modern Physics.* (Third Edition.) New York: D. Van Nostrand Company, 1948. 561 pp.

(For theoretical physics textbooks, see Chapter VI.)

Comprehensive sets.

Certain physics textbooks appear in multi-volume form:

Grimsehl, Ernst. *A Textbook of Physics,* translated from the seventh German edition. London: Blackie and Son, 1932-1935. 5 vols.

More encyclopedic in scope is:

Müller-Pouillets Lehrbuch der Physik. (11. Auflage.) Braunschweig: Friedrich Vieweg und Sohn, 1925-1934. 5 vols. in 14.

But this is dwarfed by two truly monumental compilations:

a. *Handbuch der Physik,* herausgegeben von H. Geiger und K. Scheel. (Vols. XXII-XXIV: Second Edition.) Berlin: Springer, 1926-1933. 24 vols. in 27, plus separate Sachregister (1929; 26 pp.).

b. *Handbuch der Experimentalphysik,* herausgegeben von W. Wien und F. Harms. Leipzig: Akademische Verlagsgesellschaft, 1926-1937. 26 vols. in 44, plus two supplementary volumes.

Replete with useful data, this set is an impressive addition to library holdings.

Another large German encyclopedia is:

Handwörterbuch der Naturwissenschaften, herausgegeben von R. Dittler, G. Joos, *et al.* (Zweite Auflage.) Jena: Gustav Fischer, 1931-1935. 10 vols. plus index vol.

The articles are extensive, with many biographies and bibliographies included.

Several specialized handbooks mentioned under subject[4] are based on the earlier:

Winkelmann, A. *Handbuch der Physik.* (Zweite Auflage.) Leipzig: J. A. Barth, 1905-1909. 6 vols. in 7.

Finally, an encyclopedic work of interest to the physicist, even though portions date back to the turn of the century, is:

Encyklopädie der Mathematischen Wissenschaften, mit Einschluss Ihrer Anwendungen. Leipzig: B. G. Teubner, 1898-1935. 6 vols. in 23. (Vol. 4: *Mechanik,* redigiert von Felix

4. Mechanics (Auerbach); Optics (Gehrcke); Electricity and Magnetism (Graetz).

Klein und C. H. Müller; 1901-1914, with index vol., 1935. Vol. 5: *Physik,* redigiert von A. Sommerfeld, 1903-1926.) Among its noted contributors are Abraham, Born, Lorentz, Love, *et al.* Long bibliographies are given. A second edition is in progress (Leipzig: B. G. Teubner, 1939-). There is an incomplete French edition under the title: *Encyclopédie des Sciences Mathématiques Pures et Appliquées.*

2—Mechanics

General.

For the field of mechanics there exists a comprehensive encyclopedia:

Auerbach, Felix, and Hort, W. *Handbuch der Physikalischen und Technischen Mechanik.* Leipzig: J. A. Barth, 1927-1931. 7 vols. in 8.

This well-documented set is the work of a large staff of specialists. It is one of several subject handbooks based on Winkelmann's *Handbuch der Physik.*

For interesting accounts of pioneer work in mechanics, see:

a. Hart, Ivor B. *The Mechanical Investigations of Leonardo da Vinci.* Chicago: The Open Court Publishing Company, 1925. 240 pp.

In superb format, Da Vinci's wide range of invention is set forth against contemporary backgrounds.

b. Galilei, Galileo. *Dialogues concerning Two New Sciences,* translated by Henry Crew and Alfonso de Salvio. Evanston and Chicago, Ill: Northwestern University, 1939. 300 pp.

The translators state (p. v):

> For more than a century English speaking students have been placed in the anomalous position of hearing Galileo constantly referred to as the founder of modern physical science without having any chance to read, in their own language, what Galileo himself has to say.

The "two new sciences" are mechanics and local motions.

To select a few representative general textbooks on mechanics from among so many is a difficult task, even if the engineering mechanics books are ignored for present purposes. A half-dozen well-known texts follow:

a. Jeans, Sir James H. *An Elementary Treatise on Theoretical Mechanics.* Boston: Ginn and Company, 1907. 364 pp.

Rather old, but a clear understanding of physical principles is provided.

b. Lindsay, Robert B. *Physical Mechanics; An Intermediate Text for Students of the Physical Sciences.* (Second Edition.) New York: D. Van Nostrand Company, 1950. 451 pp.

c. Reynolds, Joseph B. *Analytic Mechanics.* New York: Prentice-Hall, Inc., 1929. 347 pp.

Problems are an important feature of this book. The author clears up the meaning of "analytic" mechanics as follows (p. 1):

> A more or less artificial division of the subject matter of mechanics separates it into *elementary mechanics* and *analytic mechanics.* Elementary mechanics is a treatment of the subject using only the elementary branches of mathematics—geometry, trigonometry, and algebra. Analytic mechanics, in addition to these, employs analytic geometry, spherical trigonometry, calculus, and differential equations.

d. Clements, Guy R., and Wilson, Levi T. *Analytical and Applied Mechanics.* (Third Edition.) New York: McGraw-Hill Book Company, 1951. 463 pp.

e. Synge, John L., and Griffith, B. A. *Principles of Mechanics.* (Second Edition.) New York: McGraw-Hill Book Company, 1949. 530 pp.

f. Slater, John C., and Frank, Nathaniel H. *Mechanics.* New York: McGraw-Hill Book Company, 1947. 297 pp.

More advanced presentations include:

a. Ames, Joseph S., and Murnaghan, Francis D. *Theoretical Mechanics.* Boston: Ginn and Company, 1929. 462 pp.

b. Coe, Carl J. *Theoretical Mechanics.* New York: The Macmillan Company, 1938. 555 pp.

c. Lamb, Horace. *Higher Mechanics.* (Second Edition.) Cambridge, England: At the University Press, 1929. 292 pp.

d. Goldstein, Herbert. *Classical Mechanics.* Cambridge, Mass.: Addison-Wesley Press, 1950. 399 pp.

e. Milne, E. A. *Vectorial Mechanics.* New York: Interscience Publishers, Inc., 1948. 382 pp.

The author maintains that "vectors are not merely a pretty toy, suitable for elegant proofs of general theorems, but are a powerful weapon of workaday mathematical investigation."

Two branches of mechanics are statics and dynamics. Repre-

sentative textbooks on statics, which deals with forces in equilibrium, are:

a. Routh, Edward J. *A Treatise on Analytical Statics.* (Second Edition.) Cambridge, England: At the University Press, 1909. 2 vols.

Although old, this text (and others by the same author on dynamics) are recognized classic presentations.

b. Lamb, Horace. *Statics, including Hydrostatics and the Elements of the Theory of Elasticity.* (Third Edition.) Cambridge, England: At the University Press, 1928. 357 pp.

c. Ramsey, Arthur S. *Statics.* Cambridge, England: At the University Press, 1934. 296 pp.

For dynamics (the study of unbalanced forces), we have:

a. Routh, Edward J. *A Treatise on Dynamics of a Particle.* Cambridge, England: At the University Press, 1898. 417 pp.

b. Routh, Edward J. *The Elementary Part of a Treatise on the Dynamics of a System of Rigid Bodies.* (Eighth Edition.) London: The Macmillan Company, 1930. 443 pp.

(This is a reprint of the eighth edition (1913) which in turn was a reprint of the seventh.)

c. Routh, Edward J. *The Advanced Part of a Treatise on the Dynamics of a System of Rigid Bodies.* (Sixth Edition.) London: The Macmillan Company, 1905. 484 pp.

d. Lamb, Horace. *Dynamics.* (Second Edition.) Cambridge, England: At the University Press, 1923. 351 pp.

e. Love, Augustus E. H. *Theoretical Mechanics: An Introductory Treatise on the Principles of Dynamics.* (Third Edition.) Cambridge, England: At the University Press, 1921. 310 pp.

f. Ramsey, Arthur S. *Dynamics.* Cambridge, England: At the University Press, 1929-1937. 2 vols.

g. Whittaker, E. T. *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies.* (Fourth Edition.) Cambridge, England: At the University Press, 1937. 456 pp.

See also Searle's *Experimental Harmonic Motion.*

Gravity and friction may be included here, for they are universally encountered in dynamics. The classic presentation of the former is:

Newton, Sir Isaac. *Mathematical Principles of Natural*

Philosophy, translated into English by Andrew Motte in 1729; the translations revised, and supplied with an historical and explanatory appendix, by Florian Cajori. Berkeley, Cal.: University of California Press, 1934. 680 pp.

Newton's doctrine of gravitation is further expounded in:

Snow, A. J. *Matter and Gravity in Newton's Physical Philosophy.* London: Oxford University Press, 1926. 256 pp.

Potential theory, a branch of mathematics having electrical as well as gravitational implications, is covered by:

a. MacMillan, William D. *The Theory of the Potential.* New York: McGraw-Hill Book Company, 1930. 469 pp.

b. Ramsey, Arthur S. *An Introduction to the Theory of Newtonian Attraction.* Cambridge, England: At the University Press, 1940. 184 pp.

The contents are: (1) Preliminary mathematics; (2) Gravitational attraction and potential; (3) Attraction and potential at internal points; (4) Theorems of Laplace, Poisson and Gauss; (5) Green's theorem; (6) Harmonic functions; and (7) Attraction of ellipsoids.

c. Kellogg, Oliver D. *Foundations of Potential Theory.* Berlin: Springer, 1929. 384 pp.

Friction is treated in the following books:

a. Stanton, Thomas E. *Friction.* London: Longmans, Green and Company, 1923. 183 pp.

This collects widely scattered material on surface friction, rolling friction, viscosity, etc.

b. Gemant, Andrew. *Frictional Phenomena.* Brooklyn, N. Y.: Chemical Publishing Company, 1950. 497 pp.

The physics of friction is explained, in general and for various media such as gases, liquids, and solids.

c. Bowden, Frank P., and Tabor, D. *The Friction and Lubrication of Solids.* Oxford: At the Clarendon Press, 1950. 337 pp.

See also Palmer's résumé.[5]

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5. F. Palmer, "What about Friction?" *American Journal of Physics,* 17: 181-187; 327-335; 336-342, April and September, 1949.

Fluid mechanics.

Introductory textbooks, especially those designed for engineering instruction, are very numerous. Typical examples follow:

a. Jameson, Alexander H. *An Introduction to Fluid Mechanics.* (Second Edition.) London: Longmans, Green and Company, 1942. 245 pp.

b. Rouse, Hunter, and Howe, J. W. *Basic Mechanics of Fluids.* New York: John Wiley and Sons, 1953. 245 pp.

c. Vennard, John K. *Elementary Fluid Mechanics.* (Second Edition.) New York: John Wiley and Sons, 1947. 339 pp.

More advanced treatments of hydro- and aerodynamics (comprising fluid dynamics) include:

a. Lamb, Sir Horace. *Hydrodynamics.* (Sixth Edition.) Cambridge, England: At the University Press, 1932. 738 pp. This standard comprehensive treatise is well documented.

b. Milne-Thomson, Louis M. *Theoretical Hydrodynamics.* (Second Edition.) New York: The Macmillan Company, 1950. 600 pp.

c. Milne-Thomson, Louis M. *Theoretical Aerodynamics.* (Second Edition.) New York: D. Van Nostrand Company, 1952. 414 pp.

d. Drysdale, Charles V., *et al. The Mechanical Properties of Fluids.* (Second Edition.) London: Blackie and Son, 1936. 382 pp.

Miscellaneous essays are presented on the mathematical theory of fluid motion, viscosity and lubrication, elastic phenomena, etc.

e. Kuethe, A. M., and Schetzer, J. D. *Foundations of Aerodynamics.* New York: John Wiley and Sons, 1950. 374 pp.

f. Miles, E. R. C. *Supersonic Aerodynamics.* New York: McGraw-Hill Book Company, 1950. 255 pp.

In a joint review[6] of the last two books mentioned, J. B. Kelley cites them as an excellent combination for a "three or four semester course starting in perhaps the senior year of college and carrying on through the first year of graduate work."

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6. *Physics Today*, 4 (No. 7): 25, July 1951.

See also index under Aerodynamics and Air Flow.

Properties.

As the general properties of matter are fully discussed in most general textbooks[7] and compendia, this section will deal chiefly with elasticity, viscosity, and plasticity, comprising *rheology,* derived as follows:

> Founded in 1929 . . . the Society of Rheology was created to promote in all possible ways the study of the deformation and flow of matter. Prior to 1929, there was no single word adequate to define this particular field, including the subjects of elasticity, viscosity, and plasticity; the term "rheology" was therefore coined from the Greek "to flow" and "science" and was defined as "the science of the deformation and flow of matter." In recent years the word has become a standard part of the modern scientific vocabulary.[8]

Elasticity is reviewed on a physical basis, preparatory to mastery of its mathematical phases, in:

Southwell, R. V. *An Introduction to the Theory of Elasticity for Engineers and Physicists.* (Second Edition.) London: Oxford University Press, 1941. 509 pp.

Advanced theory is covered by:

a. Love, A. E. H. *A Treatise on the Mathematical Theory of Elasticity.* (Fourth Edition.) Cambridge, England: At the University Press, 1927. 643 pp.

This is the standard treatise on the subject, and is invaluable to physicists and engineers alike. (Dover Publications, Inc., has issued a reprint.)

b. Sokolnikoff, Ivan S. *Mathematical Theory of Elasticity.* New York: McGraw-Hill Book Company, 1946. 373 pp.

c. Timoshenko, Stephen, and Goodier, J. N. *Theory of Elasticity.* (Second Edition.) New York: McGraw-Hill Book Company, 1951. 506 pp.

Photoelasticity renders elastic effects visible for practical and theoretical study, as Coker and Filon point out:

> The practical importance of Photo-Elasticity to the engineer can hardly be overrated. It provides him, as no other existing method does, with an immediate practical solution of fundamental problems concerning the stresses in the elements of structures and machines, which cannot

7. Notably those by Newman and Searle, and by Champion and Davy.
8. *Physics Today,* 4 (No. 10): 24, October 1951.

be otherwise directly observed and which are usually beyond the reach of calculation. . . . But Photo-Elasticity has also its value for the pure Physicist, and it provides an additional means of exploring the interaction of molecules and atoms with radiation, a means to which little attention has hitherto been paid, and which should not be neglected, as it may throw much light upon the condition of matter in the solid state.[9]

Two excellent treatises are available:

a. Coker, Ernest G., and Filon, L. N. G. *A Treatise on Photoelasticity.* Cambridge, England: At the University Press, 1931. 720 pp.

Physical, mathematical, and technical effects are comprehensively covered, with an extensive bibliography (pp. 695-711). Chapter 3 is an historical summary.

b. Frocht, Max M. *Photoelasticity.* New York: John Wiley and Sons, 1941-1948. 2 vols.

Engineering aspects are emphasized along theoretical and experimental lines.

See also Elasticity in the index.

Viscosity and plasticity receive comprehensive treatment in these surveys:

a. Nádai, A. *Theory of Flow and Fracture of Solids.* (Second Edition.) Vol. 1. New York: McGraw-Hill Book Company, 1950. 572 pp.

This is a revision of the author's "Plasticity."

b. Hatschek, Emil. *The Viscosity of Liquids.* London: G. Bell and Sons, 1928. 239 pp.

c. Reiner, Markus. *Deformation and Flow.* London: H. K. Lewis and Company, 1949. 346 pp.

d. Houwink, R. *Elasticity, Plasticity and Structure of Matter.* Cambridge, England: At the University Press, 1937. 376 pp.

e. Scott Blair, G. W. *A Survey of General and Applied Rheology.* New York: Pitman Publishing Corporation, 1944. 196 pp.

Twenty-four methods of rheological measurement are mentioned on pp. 80-124.

Further references may be found in:

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9. P. xiv of their *Treatise*. . .

Kececioglu, Dimitri. *Bibliography of Plasticity.* New York: American Society of Mechanical Engineers, 1950. 191 pp.
Covering both theory and application, this comprehensive list of 40 books and 1845 articles is arranged chronologically (1837-1949), with author and subject indexes.

See also Viscosity in the index.

Micromeritics is the name applied to the technology of fine particles, larger than colloids and up to one inch diameter. The overall treatise on this new subject is:

Dalla Valle, J. M. *Micromeritics; The Technology of Fine Particles.* (Second Edition.) New York: Pitman Publishing Corporation, 1948. 555 pp.
The author states (p. vii): "There is no phase of engineering or applied science where some knowledge of particulate technology is not required."
Chapters include: Dynamics of small particles; Electrical, optical and sonic properties; Thermodynamics of particles; Capillarity.

For statistical aspects see:

Herdan, Gustav. *Small Particle Statistics.* New York: Elsevier Publishing Company, 1953. 520 pp.

High and low pressure effects.

A prominent physicist who has been engaged in experimental high pressure work for over a quarter century summarizes his own and other contributions in the following:

Bridgman, Percy W. *The Physics of High Pressure.* (New Impression with Supp.) London: G. Bell and Sons, 1949. 445 pp.
This lucid treatment has copious bibliographical references, and a historical introduction. A forty-page supplement has been added to the 1931 edition.

Low pressure (or high vacuum) practice is covered by numerous books, among which are:

a. Dushman, Saul. *Scientific Foundations of Vacuum Technique.* New York: John Wiley and Sons, 1949. 882 pp.
Based on General Electric research laboratory experimentation, it is a revision of the author's "Production and Measurement of High Vacua."

b. Yarwood, J. *High Vacuum Technique; Theory, Practice, Industrial Applications, and Properties of Materials.* (Second Edition.) New York: John Wiley and Sons, 1945. 140 pp.

c. Jnanananda, Swami. *High Vacua; Principles, Production, and Measurement.* New York: D. Van Nostrand Company, 1947. 310 pp.

d. Kaye, George W. C. *High Vacua.* London: Longmans, Green and Company, 1927. 175 pp.

Applied mechanics.

Three examples of the engineering mechanics books omitted from general treatment may be cited:

a. Timoshenko, Stephen, and Young, D. H. *Engineering Mechanics.* (Third Edition.) New York: McGraw-Hill Book Company, 1951. 517 pp.

Many illustrative examples are solved, step by step.

b. Singer, Ferdinand L. *Engineering Mechanics.* New York: Harper and Brothers, 1943. 482 pp.

c. Seely, Fred B., and Ensign, N. E. *Analytical Mechanics for Engineers.* (Fourth Edition.) New York: John Wiley and Sons, 1952. 443 pp.

See also the review series, *Advances in Applied Mechanics,* and the critical abstracts in *Applied Mechanics Reviews.*

The gyroscope is an important application of mechanics, and is best introduced by comparison with tops:[10]

Crabtree, Harold. *An Elementary Treatment of the Theory of Spinning Tops and Gyroscopic Motion.* (Second Edition.) London: Longmans, Green and Company, 1914. 193 pp.

Rotational dynamics are studied in popular style without sacrifice of scientific accuracy.

More advanced theory and applications are found in:

a. Davidson, Martin. *The Gyroscope and Its Applications.* London: Hutchinson's Scientific and Technical Publications, 1946. 256 pp.

b. Ferry, Ervin S. *Applied Gyrodynamics.* New York: John Wiley and Sons, 1933. 277 pp.

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10. There is even a four-volume handbook: F. Klein and A. Sommerfeld, *Theorie des Kreisels* (Leipzig, 1897-1910).

c. Deimel, Richard F. *Mechanics of the Gyroscope.* New York: The Macmillan Company, 1929. 192 pp.

Vibration prevention is another field of applied mechanics, treated in:

a. Den Hartog, J. P. *Mechanical Vibrations.* (Third Edition.) New York: McGraw-Hill Book Company, 1947. 478 pp.

b. Timoshenko, Stephen. *Vibration Problems in Engineering.* (Second Edition.) New York: D. Van Nostrand Company, 1937. 470 pp.

Vibration measuring instruments are well described on pp. 443-462.

c. Wilson, W. Ker. *Practical Solution of Torsional Vibration Problems.* (Second Edition.) London: Chapman and Hall, Ltd., 1940-1941. 2 vols.

A third major application of the principles of mechanics is ballistics, which has two subdivisions, according to Robinson:

> *Ballistics* is the art of hurling a projectile. It is ordinarily divided into two branches, *interior ballistics*, which deals with the projectile and its accessories while it is within the weapon, and *exterior ballistics*, which deals with the projectile from the gun to the target.[11]

Useful books on ballistics include:

a. Robinson, Clark S. *The Thermodynamics of Firearms.* New York: McGraw-Hill Book Company, 1943. 175 pp.

b. Bliss, Gilbert A. *Mathematics for Exterior Ballistics.* New York: John Wiley and Sons, 1944. 128 pp.

c. Corner, J. *Theory of the Interior Ballistics of Guns.* New York: John Wiley and Sons, 1950. 443 pp.

3—Heat

General.

Comprehensive treatises on the form of energy called heat, and its relationship with work (thermodynamics), are the following:

a. Saha, M. N., and Srivastava, B. N. *A Treatise on Heat.* (Second Edition.) Allahabad and Calcutta: The Indian Press, 1935. 815 pp.

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11. Page 2 of Robinson's "Thermodynamics..."

This is well known for its clarity of presentation.

b. Planck, Max. *Treatise on Thermodynamics.* (Third Edition.) London: Longmans, Green and Company, 1927. 297 pp.

Seven German editions have been published, attesting its usefulness.

The textbooks in this field are very numerous, especially those on applied thermodynamics intended for engineering school use. Some which are oriented towards physics follow:

a. Zemansky, Mark W. *Heat and Thermodynamics; An Intermediate Textbook for Students of Physics, Chemistry, and Engineering.* (Third Edition.) New York: McGraw-Hill Book Company, 1951. 461 pp.

Fundamental principles and applications are clearly developed, with many diagrammatic representations of systems and thermodynamic surfaces.

b. Weld, LeRoy Dougherty. *A Textbook of Heat for Upperclassmen.* New York: The Macmillan Company, 1948. 436 pp.

c. Roberts, John K. *Heat and Thermodynamics.* (Fourth Edition.) London: Blackie and Son, 1951. 593 pp.

d. Worthing, Archie G., and Halliday, David. *Heat.* New York: John Wiley and Sons, 1948. 522 pp.

e. Cork, James M. *Heat.* (Second Edition.) New York: John Wiley and Sons, 1942. 294 pp.

General backgrounds are sketched in different manners by:

a. Bridgman, Percy W. *The Nature of Thermodynamics.* Cambridge, Mass.: Harvard University Press, 1941. 229 pp.

The author makes one of his characteristic operational analyses, "in such a form as to bring out the role and the consequences of the verbal requirements which have entered into forming the concepts."[12]

b. McKie, Douglas, and Heathcote, Niels H. de V. *The Discovery of Specific and Latent Heats.* London: Edward Arnold and Company, 1935. 155 pp.

In the preface of this scholarly presentation based on original sources, E. N. da C. Andrade states (p. 4):

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12. *Op. cit.*, p. xii.

The subject with which the book deals, under its unpretentious title, is no less than the foundation of the modern science of heat, which may be said to have originated when a really clear distinction was made between heat and temperature.

Formulas for fundamental and derived entities in thermodynamics are conveniently gathered in:

Bridgman, Percy W. *A Condensed Collection of Thermodynamic Formulas.* Cambridge, Mass.: Harvard University Press, 1925. 34 pp.

Diagrams in the form of entropy charts are found in:

Gourdet, G., and Proust, A. *Les Diagrammes Thermodynamiques.* Paris: Dunod, 1950. 2 vols.

Current periodical indexing media described in Chapter II may be supplemented for early material by:

Tuckerman, Alfred. *Index to the Literature of Thermodynamics.* Washington, D. C.: Smithsonian Institution, 1890. 239 pp. (Smithsonian Miscellaneous Collections Vol. 34, No. 741.)

Kinetic theory of gases.

The conception of gases as bodies of particles in constant rebounding motion leads to fundamental laws expressed in:

a. Jeans, Sir James H. *An Introduction to the Kinetic Theory of Gases.* New York: The Macmillan Company, 1940. 311 pp.

Physical rather than mathematical aspects are emphasized.

b. Loeb, Leonard B. *The Kinetic Theory of Gases.* (Second Edition.) New York: McGraw-Hill Book Company, 1934. 687 pp.

Very lucidly, Loeb links classical deductions with recent experimentation.

c. Sears, Francis W. *An Introduction to Thermodynamics, the Kinetic Theory of Gases, and Statistical Mechanics.* (Second Edition.) Cambridge, Mass.: Addison-Wesley Press, 1953. 374 pp.

d. Massey, H. S. W., and Burhop, E. H. S. *Electronic and Ionic Impact Phenomena.* London: Oxford University Press, 1952. 669 pp.

Combustion processes are described in:

a. Lewis, Bernard, and Elbe, Guenther von. *Combustion, Flame and Explosions of Gases.* New York: Academic Press, 1951. 795 pp.

b. *Third Symposium on Combustion and Flame and Explosion Phenomena.* Baltimore: Williams and Wilkins Company, 1949. 748 pp.

Fourth Symposium. . . Same publisher, 1953. 926 pp.

"Papers of the first symposium were published in *Industrial and Engineering Chemistry,* Vol. 20, pp. 998-1057, 1928; and of the second in *Chemical Reviews,* Vol. 21, pp. 209-460, 1937, and vol. 22, pp. 1-310, 1938."

Heat flow.

An important treatise in process of publication is:

Jakob, Max. *Heat Transfer.* Vol. 1. New York: John Wiley and Sons, 1949. 758 pp.

For conduction processes, one may consult:

a. Carslaw, Horatio S., and Jaeger, J. C. *Conduction of Heat in Solids.* Oxford: At the Clarendon Press, 1947. 386 pp.

b. Ingersoll, Leonard, *et al. Heat Conduction, with Engineering and Geological Applications.* New York: McGraw-Hill Book Company, 1948. 278 pp.

Heat transfer in the engineering sense is thoroughly treated in a survey sponsored by the National Research Council:

McAdams, William H. *Heat Transmission.* (Second Edition.) New York: McGraw-Hill Book Company, 1942. 459 pp.

High and low temperature effects.

Comprehensive discussions of low temperature work are provided by:

a. Squire, Charles F. *Low Temperature Physics.* New York: McGraw-Hill Book Company, 1953. 244 pp.

b. Ruhemann, M., and Ruhemann, B. *Low Temperature Physics.* Cambridge, England: At the University Press, 1937. 313 pp.

An extensive bibliography appears on pp. 291-313.

c. Burton, Eli F.; Smith, H. G.; and Wilhelm, J. O. *Phe-*

nomena at the Temperature of Liquid Helium. New York: Reinhold Publishing Corporation, 1940. 362 pp.

A shorter summary is furnished in:

Jackson, L. C. *Low Temperature Physics.* (Second Edition.) London: Methuen and Company, 1948. 130 pp.

A special aspect, namely the remarkably high electrical conductivity encountered in the neighborhood of absolute zero (-273° C.) appears in:

a. London, Fritz. *Superfluids.* Vol. 1: *Macroscopic Theory of Superconductivity.* New York: John Wiley and Sons, 1950. 161 pp.

b. Shoenberg, David. *Superconductivity.* (Second Edition.) Cambridge, England: At the University Press, 1952. 256 pp.

c. Laue, Max von. *Theory of Superconductivity.* New York: Academic Press, 1952. 140 pp.

See also the London Science Museum publication on this subject, Casimir's book, and two recent low-temperature symposia reported in U. S. National Bureau of Standards Circulars 519 and 520, G. P. O., 1952.

For high temperatures, especially their measurement by instruments known as pyrometers, we have available:

a. Burgess, G. K., and LeChatelier, H. *The Measurement of High Temperatures.* (Third Edition.) New York: John Wiley and Sons, 1912. 510 pp.

Although old, this is still important as a well-documented survey from historical, theoretical and practical viewpoints.

b. Wood, William P., and Cork, James M. *Pyrometry.* (Second Edition.) New York: McGraw-Hill Book Company, 1941. 263 pp.

This is designed as a textbook and a practical treatise as well.

See also Temperature in the index.

Applied thermodynamics.

An interesting translation of a French classic on *heat engines* is:

Carnot, Sadi. *Reflections on the Motive Power of Heat. and on Machines fitted to Develop this Power.* Translated by R. H.

Thurston. New York: American Society of Mechanical Engineers, 1943. 107 pp.
The 1824 work is here presented in superb format, accompanied by a biography of Carnot.

Clean-cut diagrams in color are a noteworthy feature of:

Wrangham, D. A. *The Theory and Practice of Heat Engines.* Cambridge, England: At the University Press, 1942. 756 pp.

See also Andrade's *Engines,* and Robinson's *Thermodynamics of Firearms.*

Heat power is a branch of mechanical engineering beyond the limits of this guide; one may consult Kent's or Mark's handbooks in that field, as well as comprehensive textbooks such as:

a. Allen, John R., and Bursley, Joseph A. *Heat Engines; Steam, Gas, Steam Turbines, and their Auxiliaries.* (Fifth Edition.) New York: McGraw-Hill Book Company, 1941. 576 pp.

b. Barnard, William N.; Ellenwood, Frank O.; and Hirshfeld, Clarence F. *Heat Power Engineering.* (Third Edition.) New York: John Wiley and Sons, 1926-1933. 3 vols.

4—Sound

General.

The outstanding classic in advanced acoustical theory is the following treatise:

Rayleigh, John W. S. *The Theory of Sound.* (Second Edition.) London: The Macmillan Company, 1926. 2 vols.
There is also a single volume photo-reproduction (New York: Dover Publications, 1945) that incorporates a historical introduction by Robert B. Lindsay, who states:

> It is scarcely an exaggeration to say that there is no vibrating system likely to be encountered in practice which cannot be tackled successfully by the methods set forth in the first ten chapters of Rayleigh's treatise. Even the worker in the field of non-linear systems, a department of increasing practical importance in modern vibration theory, will find useful basic hints in Rayleigh.

Based largely on the foregoing is the equally well known:

Lamb, Horace. *The Dynamical Theory of Sound.* (Second

Edition.) London: Edward Arnold and Company, 1925. 307 pp.

Mathematical treatments appear also in the following advanced textbooks:

a. Morse, Philip M. *Vibration and Sound.* (Second Edition.) New York: McGraw-Hill Book Company, 1948. 468 pp.

b. Stewart, George W., and Lindsay, Robert B. *Acoustics; A Text on Theory and Applications.* New York: D. Van Nostrand Company, 1930. 358 pp.

c. Crandall, Irving B. *Theory of Vibrating Systems and Sound.* New York: D. Van Nostrand Company, 1926. 272 pp.

Some introductory textbooks on acoustics follow:

a. Wood, Albert B. *A Textbook on Sound.* (Second Edition.) London: G. Bell and Sons, 1941. 578 pp.

This is an excellent account of the physics of mechanical vibrations, both audible and inaudible. Many interesting applications are described, such as echo sounding, sound ranging, sound motion pictures, etc. Sound measurement, analysis, and recording are well summarized.

b. Richardson, Edward G. *Sound; A Physical Textbook.* (Fifth Edition.) London: Edward Arnold and Company, 1953. 352 pp.

c. Randall, Robert H. *An Introduction to Acoustics.* Cambridge, Mass.: Addison-Wesley Press, 1951. 340 pp.

d. Wood, Alexander. *Acoustics.* New York: Interscience Publishers, Inc., 1941. 588 pp.

(This should not be confused with the first book of this group.)

e. Watson, Floyd R. *Sound; An Elementary Textbook on the Science of Sound and the Phenomena of Hearing.* New York: John Wiley and Sons, 1935. 219 pp.

"Reference books on sound" (pp. vii-ix) is an excellent annotated bibliography, and the last chapter outlines 19 experiments on sound.

For acoustic measurements see Beranek in conjunction with:

Rao, V. V. L. *The Decibel Notation; Its Application to Radio and Acoustics,* Brooklyn, N. Y.: Chemical Publishing Company, 1946. 179 pp.

Physiological acoustics.

The word "sound" may connote the sensation of hearing, as well as the vibratory disturbances capable of producing it. The classic discussion of this interrelationship is:

Helmholtz, Hermann L. F. von. *On the Sensations of Tone as a Physiological Basis for the Theory of Music,* translated and revised by Alexander J. Ellis. (Fourth Edition.) London: Longmans, Green and Company, 1912. 575 pp.

Its three parts are: (1) On the composition of vibrations; (2) On the interruptions of harmony; and (3) The relationship of musical tones.

More recent presentations, developed from physical and physiological backgrounds, respectively, are:

a. Fletcher, Harvey. *Speech and Hearing in Communication.* New York: D. Van Nostrand Company, 1953. 461 pp.

This brings to date the author's earlier *Speech and Hearing.* Some chapter titles are: The speech sounds of English; The speaking mechanism; Characteristics of speech waves; Noise; Mechanism of hearing; Minimum perceptual changes in frequency and sound pressure level; Loudness.

b. Stevens, Stanley S., and Davis, Hallowell. *Hearing; Its Psychology and Physiology.* New York: John Wiley and Sons, 1938. 489 pp.

Very useful are the glossary (pp. 449-456), and the bibliography (pp. 457-472). Its joint authorship by a psychologist and physiologist is aptly defended by their comment (p. xi):

> It is the characteristic of the science of audition that it ignores the traditional boundaries between the sciences. None of the traditional disciplines nor any of the academic departments of the modern university can claim audition exclusively as its own. The mystery of the ear inspires the psychologist, the physiologist, the otologist, and the physicist alike.

Musical acoustics from the physicist's viewpoint is the subject of:

a. Jeans, Sir James H. *Science and Music.* New York: The Macmillan Company, 1937. 258 pp.

The style of this book is pleasantly non-technical.

b. Wood, Alexander. *The Physics of Music.* Cleveland, Ohio: The Sherwood Press, 1944. 255 pp.
The author describes the "very interesting borderland between physics and music."

c. Culver, Charles A. *Musical Acoustics.* (Third Edition.) Philadelphia: The Blakiston Company, 1951. 215 pp.

d. Olson, Harry F. *Musical Engineering; An Engineering Treatment of the Interrelated Subjects of Speech, Music, Musical Instruments, Acoustics, Sound Reproduction, and Hearing.* New York: McGraw-Hill Book Company, 1952. 369 pp.

The relation of the physical principles of sound to music from the musician's standpoint is delineated in:

Bartholomew, Wilmer T. *Acoustics of Music.* New York: Prentice-Hall, Inc., 1942. 242 pp.
An extensive bibliography is appended (pp. 231-238). The author asserts (p. vii):

> The Taj Mahal, that dream of architectural loveliness, seems to our entranced vision far removed from such mundane things as the measurement of angles, the stresses and strains of building materials, and the chemistry of pigments. But is it not related to these matters as the harvest is to the seed? Beethoven's Ninth Symphony, that last mighty dream of a stormy soul, or *L'après midi*, that more delicate dream of fragile beauty, seems to our transported ears to have no connection with such prosaic things as the compressibility of air, the reflection of sound waves by walls, or the mathematics of Fourier analysis. But there is a connection, unrecognized and scorned though it be by many.

Diametrically opposed to musical tones are the discordant sounds treated in:

McLachlan, Norman W. *Noise; A Comprehensive Survey from Every Point of View.* London: Oxford University Press, 1935. 148 pp.
It discusses the origin, measurement, effects and reduction of various types of noise, and lists further references on pp. 139-145.

Ultrasonics.

Sound waves become inaudible to the average individual when of higher frequency than twenty kilocycles. Introduc-

tory acquaintance with ultrasonic phenomena is provided by Hubbard's survey[13] and by:

Wood, Robert Williams. *Supersonics; The Science of Inaudible Sounds.* Providence, R. I.: Brown University, 1939. (Reprinted 1948 with sup. bibl.) 164 pp.

Reviewing it in *Physics Today,* 2 (No. 2): 29, February 1949, Elias Klein states:

> Nowadays, supersonics pertains to speed above the normal sound velocity in air, while ultrasonics deals with high frequency inaudible sound waves. Therefore, the title of this book may be somewhat confusing, but its contents reveal clearly the early developments of ultrasound. . . . For essential background material in ultrasonics, this book remains an excellent primer, in spite of the outstanding technological advances which have been made in this field during the past ten years.

More extensive treatments are as follows:

a. Bergmann, Ludwig. *Der Ultraschall und Seine Anwendung in Wissenschaft und Technik.* (Fünfte Auflage.) Stuttgart: S. Hirzel, 1949. 748 pp.

This well-documented treatise, covering generation, detection, measurement, and applications, is also available in an earlier and less comprehensive English edition (London: G. Bell and Sons, 1938. 264 pp.)

b. Carlin, Benson. *Ultrasonics.* New York: McGraw-Hill Book Company, 1949. 270 pp.

c. Richardson, Edward G. *Ultrasonic Physics.* New York: Elsevier Publishing Company, 1952. 285 pp.

This features the ultrasonic interferometer as a precision tool in physics laboratories.

d. Vigoreux, Paul. *Ultrasonics.* New York: John Wiley and Sons, 1951. 163 pp.

Some chapter headings are: Generation; Propagation; Observation; Gases; Liquids.

Further references may be found in:

Curry, Beth, *et al. Bibliography: Supersonics or Ultrasonics, 1926 to 1949, with Supplement to 1950.* Stillwater, Okla.:

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13. J. C. Hubbard, "Ultrasonics — A Survey." *American Journal of Physics,* 8: 207-221, August 1940.

Oklahoma Agricultural and Mechanical College, 1951. 277 pp.

Applied acoustics.

Useful reference compendia on all phases of modern acoustics are:

a. Olson, Harry F. *Elements of Acoustical Engineering.* (Second Edition.) New York: D. Van Nostrand Company, 1947. 539 pp.

b. Richardson, Edward G., editor. *Technical Aspects of Sound.* New York: Elsevier Publishing Company, 1953-1954. 2 vols.

This collective survey represents the work of many outstanding contributors.

Of architectural interest are:

a. Knudsen, Vern O., and Harris, C. M. *Acoustical Designing in Architecture.* New York: John Wiley and Sons, 1950. 457 pp.

b. Watson, Floyd R. *Acoustics of Buildings, including Acoustics of Auditoriums and Soundproofing of Rooms.* (Third Edition.) New York: John Wiley and Sons, 1941. 171 pp.

Practical books on sound recording include:

a. Frayne, John G., and Wolfe, Halley. *Elements of Sound Recording.* New York: John Wiley and Sons, 1949. 686 pp.

b. Read, Oliver. *The Recording and Reproduction of Sound.* (Second Edition.) Indianapolis, Ind.: Howard W. Sams and Company, 1952. 790 pp.

5—Light

General.

Although it champions the corpuscular theory of light, which at one time was generally discredited, the following is a classic in the field of optics:

Newton, Sir Isaac. *Opticks,*[14] *or a Treatise of the Reflections, Refractions, Inflections and Colours of Light.* (Reprinted from the Fourth Edition, 1730.) London: G. Bell and Sons, 1931. 414 pp.

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14. Also reissued by Dover Publications, New York, in 1952.

In the Introduction (pp. xi-xii), E. T. Whittaker states:

> The curious blending of corpuscular-theory with wave-theory which is suggested in some parts of his work, and which was a stumbling-block to the physicists of the nineteenth century, has been found to present considerable analogies with the modern views ... So the volume which is here reprinted, after being esteemed for three generations chiefly as a historical landmark displaying a marvelous combination of theoretical and experimental skill, is now once more being read for its living scientific interest.

Three well-known textbooks on the theory of light are:

a. Houstoun, Robert A. *A Treatise on Light.* (Seventh Edition.) London: Longmans, Green and Company, 1938. 528 pp.

The format and illustrations are excellent in this well-designed textbook, which has been reprinted in 1943.

b. Preston, Thomas. *The Theory of Light.* (Fifth Edition.) London: The Macmillan Company, 1928. 643 pp.

c. Hardy, Arthur, and Perrin, Fred H. *The Principles of Optics.* New York: McGraw-Hill Book Company, 1932. 632 pp.

This is suitable for students contemplating careers in optics, physics, or engineering.

Among books which give considerable space to experimental aspects one finds:

a. Jenkins, Francis A., and White, Harvey E. *Fundamentals of Optics.* (Second Edition.) New York: McGraw-Hill Book Company, 1950. 647 pp.

b. Monk, George S. *Light; Principles and Experiments.* New York: McGraw-Hill Book Company, 1937. 477 pp.

In this intermediate text on all branches of optics are presented twenty-three experiments (pp. 343-416).

c. Valasek, Joseph. *Introduction to Theoretical and Experimental Optics.* New York: John Wiley and Sons, 1949. 454 pp.

Geometrical Optics

Rectilinear paths of light are the subject of:

Southall, James P. C. *Mirrors, Prisms and Lenses; A Textbook of Geometrical Optics.* (Third Edition.) New York: The Macmillan Company, 1933. 806 pp.

Lucid ray-diagrams also are featured in these smaller general texts:

a. Edser, Edwin. *Light for Students.* London: The Macmillan Company, 1931. 591 pp.

b. Bray, F. *Light.* (Second Edition.) London: Edward Arnold and Company, 1938. 369 pp.

Physical Optics

Phenomena associated with the vibrational wave characteristics of light are dealt with in physical optics, which has a comprehensive reference work:

Gehrcke, Ernst. *Handbuch der Physikalischen Optik.* Leipzig: J. A. Barth, 1926-1928. 2 vols. in 5.

This well-documented and illustrated set has full indexes in its last volume.

Two of the best-known textbooks on the subject are:

a. Wood, Robert W. *Physical Optics.* (Third Edition.) New York: The Macmillan Company, 1934. 846 pp.

In stressing experimental aspects, the author attempts to present a "physical picture of the processes usually described by equations." Interferometers, refractometers, and other instruments are fully described.

b. Robertson, John K. *Introduction to Physical Optics.* (Third Edition.) New York: D. Van Nostrand Company, 1941. 512 pp.

An intermediate text, it is intended to provide a comprehensive introduction for the beginning student, the specialist in other fields, and the general reader.

The special topics of diffraction and scattering are treated in:

a. Meyer, Charles F. *The Diffraction of Light, X-rays, and Material Particles.* Chicago: University of Chicago Press, 1934. 473 pp.

(Also a "second revised edition": Ann Arbor, Mich., J. W. Edwards, 1949. 473 pp.)

b. Bhagavantam, S. *Scattering of Light and the Raman Effect.* Brooklyn, N. Y.: Chemical Publishing Company, 1942. 333 pp.

For experiments and measurements in optics, see Chapter V.

Spectroscopy.

Early book and periodical material on spectroscopy may be found in the following indices:

Tuckerman, Alfred. *Index to the Literature of the Spectroscope.* Washington, D. C.: Smithsonian Institution, 1888. 423 pp. (Smithsonian Miscellaneous Collections, Vol. 32, No. 658.)

Index ... 1887 through 1900. 1902. 373 pp. (Smithsonian Miscellaneous Collections, Vol. 41, No. 1312.)

The very comprehensive classic compendium is:

Kayser, H. *Handbuch der Spectroscopie.* Leipzig: S. Hirzel, 1900-1934. 8 vols.

Vols. 5 and 6 are extensive collections of spectrographic data, revised in Vols. 7 and 8 for elements in the first part of the alphabet only. It is doubtful that publication will be completed.

Useful tabulations are represented by the following:

a. Moore, C. E. *Atomic Energy Levels as Derived from the Analyses of Optical Spectra.* Washington, D. C.: Government Printing Office, 1949-. Vols. 1- (In Process.) (U. S. National Bureau of Standards Circular No. 467.)

Because the accumulation of data on atomic spectra has been so great since 1932, this set will gradually supersede the Bacher and Goudsmit work, next cited.

b. Bacher, Robert F., and Goudsmit, Samuel. *Atomic Energy States, as Derived from the Analyses of Optical Spectra.* New York: McGraw-Hill Book Company, 1932. 562 pp.

This serves in place of unpublished portions of the preceding entry, pending its completion.

c. Massachusetts Institute of Technology. *Wavelength Tables, with Intensities in Arc, Spark, or Discharge Tube of more than 100, 000 Spectrum Lines Emitted by the Atomic Elements,* measured and compiled under the direction of George R. Harrison. New York: John Wiley and Sons, 1939. 429 pp.

d. Twyman, F., and Smith, D. M. *Wavelength Tables for Spectrum Analysis.* (Second Edition.) London: Adam Hilger, Ltd., 1931. 180 pp.

References to additional tables may be found on pp. 221-229

of Sawyer's *Experimental Spectroscopy;* also in Brode's *Chemical Spectroscopy,*[15] and in the Herzberg series, below.

Well-documented textbooks prepared with the beginner's needs in view are:

a. Herzberg, Gerhard. *Atomic Spectra and Atomic Structure.*[16] New York: Prentice-Hall, Inc., 1937. 257 pp.

b. Herzberg, Gerhard. *Molecular Spectra and Molecular Structure.* New York: D. Van Nostrand Company, 1945-1950. 2 vols., as follows:

Vol. 1: *Spectra of Diatomic Molecules.* (Second Edition.) 1950. 658 pp.

Vol. 2: *Infrared and Raman Spectra of Polyatomic Molecules.* 1945. 632 pp.

c. Sommerfeld, Arnold. *Atomic Structure and Spectral Lines,* translated from fifth German edition. (Third Edition.) London: Methuen and Company, 1934; Supp.: *Wave Mechanics.*[17] London: Methuen and Company, 1930.

More advanced, and still valuable for its fundamental theory, tables, etc., is the following treatise:

Condon, E. U., and Shortley, G. H. *The Theory of Atomic Spectra.* Cambridge, England: At the University Press, 1951. 441 p. (Reprinted with corrections.)

The bands beyond the visible spectrum are treated by:

a. Koller, Lewis R. *Ultraviolet Radiation.* New York: John Wiley and Sons, 1952. 270 pp.

b. Barnes, R. B., *et al. Infrared Spectroscopy; Industrial Applications and Bibliography.*[18] New York: Reinhold Publishing Corporation, 1944. 236 pp.

See also index under Spectroscopy.

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15. W. R. Brode, *Chemical Spectroscopy,* pp. 74-84. (Second Edition.) New York: John Wiley and Sons, 1943.
16. A reprint issued by Dover Publications (New York, 1944) incorporates a few changes and additions.
17. See revised German edition (Braunschweig: Friedrich Vieweg und Sohn, 1939).
18. The main text is reprinted from *Industrial and Engineering Chemistry, Analytical Edition,* 15: 659-709, November 1943.

Physiological optics.

Parelleling similar work by the same author in the field of sound, we have the classic treatise on the physical, physiological, and psychological effects of light:

Helmholtz, Hermann L. F. von. *Treatise on Physiological Optics,* translated from the 3d German edition. Edited by James P. C. Southall. New York: Optical Society of America, 1924-1925. 3 vols.

Two presentations by physicists are:

a. Southall, James P. C. *Introduction to Physiological Optics.* London: Oxford University Press, 1937. 426 pp.

b. Houstoun, Robert A. *Vision and Colour Vision.* London: Longmans, Green and Company, 1932. 238 pp.

From physiological standpoints, we have:

a. Bartley, S. H. *Vision; A Study of the Basis.* New York: D. Van Nostrand Company, 1941. 350 pp.

b. Luckiesh, Matthew,[19] and Moss, Frank K. *The Science of Seeing.* New York: D. Van Nostrand Company, 1937. 548 pp

Color.

Books on colorimetry, the measurement of color, have already been listed under Special Measurements in Chapter V. Reference was made to the unreliability of color specification by color samples. However, collections of color chips have practical uses for purposes of matching, combination and arrangement, and are found in:

a. Jacobson, Egbert; Granville, Walter C.; and Foss, Carl E. *Color Harmony Manual.* (Third Edition.) Chicago: Container Corporation of America, 1948. 51 pp. text and 37 charts containing 973 separate color samples. Color designations of the detachable hexagon chips differ from the previous editions. (See book review in *Physics Today,* 3 (No. 8): 34-36, August 1950.)

b. Jacobson, Egbert. *Basic Color; An Interpretation of the Ostwald Color System.* Chicago: Paul Theobald, 1948. 207 pp.

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19. See also his *Reading as a Visual Task.*

c. Munsell, A. H. *Munsell Book of Color.* (Standard Edition.) Baltimore: Munsell Color Company, 1929. 2 vols.
This is a superb oversize set with fine color plates in the second volume.

d. Maerz, Aloys, and Paul, M. R. *A Dictionary of Color.* (Second Edition.) New York: McGraw-Hill Book Company, 1950. 206 pp.
This book of plates serves to correlate colors with their common names. The pages are marked off in squares, carefully color-graded, with names printed on dummy sheets opposite. Bibliographies, definitions, and techniques are included.

Terms used in English industry and science are coordinated and compared with American usage in:

Physical Society (London). *Report on Colour Terminology.* London: The Society, 1948. 56 pp.

A long-awaited American committee report furnishes an authoritative and comprehensive reference work on all phases of color:

Optical Society of America. Committee on Colorimetry. *The Science of Color.* New York: Thomas Y. Crowell Company, 1953. 385 pp.
Physical, psychological and physiological aspects are treated, in addition to colorimetry *per se.*

Interesting introductory treatments of color theory and practice are:

a. Evans, Ralph M. *An Introduction to Color.* New York: John Wiley and Sons, 1948. 340 pp.
The author's purpose is stated (p. v):

> Color sprawls across the three enormous subjects of physics, physiology, and psychology. In the past it has been rare that any intensive worker in color has had the opportunity of understanding all three phases. It is to fill this gap that the book has been written.

b. Judd, Deane B. *Color in Business, Science, and Industry.* New York: John Wiley and Sons, 1952. 401 pp.
This includes discussion of standards, measurements, etc.

c. Houstoun, Robert A. *Light and Colour.* London: Longmans, Green and Company, 1923. 179 pp.

d. Luckiesh, Matthew. *Color and its Applications.* New York: D. Van Nostrand Company, 1915. 357 pp.

e. Murray, Humphrey D., editor. *Colour in Theory and Practice.* (New Edition.) London: Chapman and Hall, Ltd., 1952. 360 pp.

For a history of color theory, see Halbertsma's book.

Luminescence embraces the color phenomena of fluorescence and phosphorescence. Some substances exposed to short waves (like ultraviolet or X-rays) absorb them and emit longer waves. If such fluorescence persists after removal of the light source, it is termed phosphorescence. Three useful references follow:

a. Pringsheim, Peter. *Fluorescence and Phosphorescence.* New York: Interscience Publishers, Inc., 1949. 794 pp.

b. Leverenz, Humboldt W. *An Introduction to Luminescence of Solids.* New York: John Wiley and Sons, 1950. 569 pp.

c. American Physical Society. *Properties and Characteristics of Solid Luminescent Materials.* New York: John Wiley and Sons, 1948. 459 pp.

Applied optics.

Technical presentations that deal more thoroughly with optical instrument design than the descriptive books cited in Chapter V under Instruments include:

a. Jacobs, Donald H. *Fundamentals of Optical Engineering.* New York: McGraw-Hill Book Company, 1943. 487 pp.

b. Martin, Louis C. *Technical Optics.* (Revised and Enlarged Edition.)[20] London: Sir Isaac Pitman and Sons, 1948-1950. 2 vols.

c. Conrady, A. E. *Applied Optics and Optical Design.* Part One. London: Oxford University Press, 1929. 518 pp.

d. Czapski, Siegfried, and Eppenstein, Otto. *Grundzüge der Theorie der Optischen Instrumente nach Abbe.*[21] (Dritte

20. Of his *An Introduction to Applied Optics.* London: Sir Isaac Pitman and Sons, 1930-1932. 2 vols.

21. See also M. v. Rohr, *Geometrical Investigation of the Formation of Images in Optical Instruments.* (Vol. 1 of "The Theory of Optical Instruments.") London: His Majesty's Stationery Office, 1920. 612 pp.

Auflage.) Leipzig: J. A. Barth, 1924. 747 pp.
This well-illustrated series of articles embodies the work of Abbe and others associated with the famous Zeiss works.[22]

Illuminating engineering is beyond the scope of this guide, but a few useful references follow:

a. Moon, Parry H., and Spencer, Domina E. *Lighting Design.* Cambridge, Mass.: Addison-Wesley Press, 1948. 482 pp.

b. Kraehenbuehl, John O. *Electric Illumination.* (Second Edition.) New York: John Wiley and Sons, 1951. 446 pp.

c. Barrows, William E. *Light,Photometry and Illuminating Engineering.* (Third Edition.) New York:McGraw-Hill Book Company, 1951. 415 pp.

The chemical effects of light, and their practical application in photography, are discussed in:

a. Dhar, Nil R. *The Chemical Action of Light.* London: Blackie and Son, 1931. 512 pp.

b. Mees, C. E. K. *The Theory of the Photographic Process.* New York: The Macmillan Company, 1942. 1124 pp.
Mees states (p. xi):

> The theory of the photographic process involves a study of the light-sensitive layers used, of the factors which control their sensitivity to light, of the changes induced in them by the action of light, of the nature of development, and of the properties of the final image and its relation in tone values to the tone values of the scene from which it was produced.

c. Mack, Julian E., and Martin, Miles J. *The Photographic Process.* New York: McGraw-Hill Book Company, 1939. 586 pp.
This is a college text from the scientific viewpoint, and includes thirty-one experiments (pp. 523-568), e.g., Perspective and angle of view; Exposure; Photomicrography.

d. Boucher, Paul E. *Fundamentals of Photography.* (Second Edition.) New York: D. Van Nostrand Company, 1947. 395, 53 pp.
The physics and chemistry of photography are stressed. There

22. See F. Auerbach, *The Zeiss Works and the Carl Zeiss Foundation in Jena.* (Translated from the fifth German edition.) London: W. and G. Foyle, Ltd., 1927. 273 pp.

are twenty-five laboratory experiments (pp. 313-395), such as: Study of lenses and diaphragms; Study of the aberrations of a lens; Making pictures with infra-red radiation; Making pictures with X-rays.

See also C. W. Miller, "Photography in the Physics Curriculum." *American Journal of Physics,* 9: 107-110, April 1941; and Eastman Kodak's *Monthly Abstract Bulletin.*

6—Electricity and Magnetism

General.

There is available a very comprehensive German handbook:

Graetz, L., editor. *Handbuch der Elektrizitat und des Magnetismus.* Leipzig: J. A. Barth, 1918-1928. 5 vols.

A large staff of specialists has contributed signed articles, with copious bibliographical citation. Volume titles are: (Vol. 1) Elektrizitatserregung und elektrostatik; (Vol. 2) Stationäre strome; (Vol. 3) Elektronen und ionen; (Vol. 4) Magnetismus und elektromagnetismus; and (Vol. 5) Zeitliche vorgänge. Technik.

Bibliographies include a historical compilation by a master bibliographer:

Mottelay, Paul F. *Bibliographical History of Electricity and Magnetism.* London: Charles Griffin and Company, 1922. 673 pp.

It is chronologically arranged, from 2637 B. C. to 1821 A. D., and incorporates biographical, historical and bibliographical material serving to identify early works.

Books appearing during an eventful quarter-century are listed in:

May, G. *A Bibliography of Electricity and Magnetism 1860 to 1883 with Special Reference to Electro-technics.* London: Trübner and Company, 1884. 203 pp. (Also a volume covering 1876-1885, published in London by Whitaker in 1886.)

Textbooks on electricity and magnetism are so numerous as to make selection of the following typical ones difficult:

a. Starling, Sydney G. *Electricity and Magnetism for Advanced Students.* (Seventh Edition.) London: Longmans, Green and Company, 1942. 630 pp.

This well-organized textbook has been so widely used as to

require over seventeen printings and editions in all, since its introduction in 1912.

b. Loeb, Leonard B. *Fundamentals of Electricity and Magnetism.* (Third Edition.) New York: John Wiley and Sons, 1947. 669 pp.
The mathematical approach is emphasized in this text for engineering and physics students.

c. Gilbert, Norman E. *Electricity and Magnetism.* (Third Edition.) New York: The Macmillan Company, 1950. 269 pp.
An intermediate textbook, it keeps physics aspects in the foreground.

d. Page, Leigh, and Adams, Norman I. *Principles of Electricity; An Intermediate Text in Electricity and Magnetism.* (Second Edition.) New York: D. Van Nostrand Company, 1949. 619 pp.
Principles rather than applications are stressed.

e. Harnwell, Gaylord P. *Principles of Electricity and Electromagnetism.* (Second Edition.) New York: McGraw-Hill Book Company, 1949. 670 pp.
Classical phenomena and modern developments are outlined, with emphasis upon experimental aspects.

f. Smythe, William R. *Static and Dynamic Electricity.* (Second Edition.) New York: McGraw-Hill Book Company, 1950. 616 pp.
This advanced textbook is also useful to the experimental research physicist.

For experiments and measurements in electricity, see Chapter V.

Electromagnetic theory.

Modern field theory stems largely from the pioneer work embodied in the following classic treatise:

Maxwell, James Clerk. *A Treatise on Electricity and Magnetism.* (Third Edition.) Oxford: At the Clarendon Press, 1904. 2 vols.

See also his *Scientific Papers* (Cambridge University Press, 1890) very compactly reproduced in one volume by Dover Publications, New York, in 1952.

Those who wish an interesting glimpse of the formative stages of Maxwell's contributions may refer to:

Larmor, Sir Joseph. *Origins of Clerk Maxwell's Electric Ideas as Described in Familiar Letters to William Thomson.* Cambridge, England: At the University Press, 1937. 56 pp.
"The letters now published present a sharp and crisp account of the genesis and rapid progress of Clerk Maxwell's ideas as he groped towards a structural theory of the electric and magnetic field."

The theory was expanded and clarified by Heaviside,[23] who further developed the mathematical methods involved:

Heaviside, Oliver. *Electromagnetic Theory.* (Complete and unabridged edition of Volumes I, II, III.) New York: Dover Publications, 1950. 386 pp.
This reproduction of the classic treatise (first published 1893-1912) has a biography by Ernst Weber.

Most widely used expositions of the subject are:

a. Jeans, Sir James H. *The Mathematical Theory of Electricity and Magnetism.* (Fifth Edition.) Cambridge, England: At the University Press, 1941. 652 pp.

b. Abraham, Max, and Becker, Richard. *The Classical Theory of Electricity and Magnetism.* (Second Edition.) London: Blackie and Son, 1950. 289 pp.
This is an English translation of the eighth German edition of Vol. 1 of their two-volume set[24] entitled *Theorie der Elektrizität.*

Historical considerations are retraced in:

O'Rahilly, Alfred. *Electromagnetics; A Discussion of Fundamentals.* London: Longmans, Green and Company, 1938. 884 pp.
An excellent selective bibliography on pp. 860-878 may be used to supplement Mottelay's work. This is a critical treatise by a mathematical physicist.

A concise but clear résumé is furnished by:

Duff, A. Wilmer, and Plimpton, Samuel J. *Elements of*

23. For other Heaviside contributions, see L. Cohen's and E. J. Berg's books.

24. Its second volume treats electron theory, and is available in *German* (Sixth Edition; Leipzig: Teubner, 1933); Reprinted by Edwards Brothers, Ann Arbor, Mich., 1944. 400 pp.

Electro-Magnetic Theory. Philadelphia: The Blakiston Company, 1940. 173 pp.

More comprehensive textbooks include:

a. Stratton, Julius A. *Electromagnetic Theory.* New York: McGraw-Hill Book Company, 1941. 615 pp.

b. Slater, John C., and Frank, Nathaniel H. *Electromagnetism.* New York: McGraw-Hill Book Company, 1947. 240 pp.

c. Attwood, Stephen S. *Electric and Magnetic Fields.* (Third Edition.) New York: John Wiley and Sons, 1949. 475 pp.

d. Mason, Max, and Weaver, Warren. *The Electromagnetic Field.* Chicago: University of Chicago Press, 1929. 390 pp.

Electromagnetic waves[25] that make radio communication possible, are discussed in:

a. Ware, Lawrence A. *Elements of Electromagnetic Waves.* New York: Pitman Publishing Corporation, 1949. 203 pp.

b. Slater, John C. *Microwave Electronics.* New York: D. Van Nostrand Company, 1950. 406 pp.

c. Skilling, Hugh H. *Fundamentals of Electric Waves.* (Second Edition.) New York: John Wiley and Sons, 1948. 245 pp.

d. Schelkunoff, S. A. *Electromagnetic Waves.* New York: D. Van Nostrand Company, 1943. 530 pp.

e. Ramo, Simon, and Whinnery, J. R. *Fields and Waves in Modern Radio.* (Second Edition.) New York: John Wiley and Sons, 1953. 576 pp.

See also books on radio mentioned in Chapter X—Electronics.

Circuits.

Heaviside's work again comes to view in:

Cohen, Louis. *Heaviside's Electrical Circuit Theory.* New York: McGraw-Hill Book Company, 1928. 169 pp.

Cohen states the purpose of his presentation (p. v) as follows:

> The importance of Heaviside's contributions to electrical theory is now generally recognized and appreciated. His teachings nevertheless are available to only a comparatively few; to the many engineers and

25. For a unified mathematical treatment of the common types of wave motion in general, see C. A. Coulson, *Waves.* (Fourth Edition.) New York: Interscience Publishers, Inc., 1947. 171 pp.

physicists who could profit much by it, the work of Heaviside is more or less a sealed book.

Practical considerations place electric circuits within the purview of electrical engineering textbooks, such as:

a. Pender, Harold, and Warren, S. Reid. *Electric Circuits and Fields.* New York: McGraw-Hill Book Company, 1943. 534 pp.
"Much of the information that the student has acquired in his course in physics is reviewed in detail."

b. Frazier, Richard H. *Elementary Electric-circuit Theory.* New York: McGraw-Hill Book Company, 1945. 434 pp.

c. Massachusetts Institute of Technology. *Electric Circuits.* New York: John Wiley and Sons, 1943. 782 pp.
This well-written and comprehensive textbook has an extensive annotated bibliography, pp. 757-767.

d. Knight, Abner R., and Fett, Gilbert H. *Introduction to Circuit Analysis.* New York: Harper and Brothers, 1943. 447 pp.
"The emphasis is placed upon the understanding of the physics of the problem, rather than upon detailed methods which have been developed for special cases."

e. Fish, Fred A. *Fundamental Principles of Electric and Magnetic Circuits.* (Third Edition.) New York: McGraw-Hill Book Company, 1940. 229 pp.

See also Electronic Tubes and Circuits.

Properties.

Magnetic, dielectric and piezoelectric phenomena are associated with certain kinds of materials. For magnetism, the following group of treatises covers varied aspects:

a. Stoner, Edmund C. *Magnetism and Matter.* London: Methuen and Company, 1934. 575 pp.
Magnetic properties of matter in general are discussed.

b. Williams, Samuel R. *Magnetic Phenomena; An Elementary Treatise.* New York: McGraw-Hill Book Company, 1931. 230 pp.
The author seeks to encourage research in such areas as Magneto-magnetics, Magneto-mechanics, Magneto-acoustics, Magneto-optics, etc.

c. Bozorth, Richard M. *Ferromagnetism.* New York: D. Van Nostrand Company, 1951. 968 pp.

d. Bates, Leslie F. *Modern Magnetism.* (Third Edition.) Cambridge, England: At the University Press, 1951. 506 pp. Experimental aspects are stressed for greater clarity of presentation.

e. Casimir, H. B. G. *Magnetism and Very Low Temperatures.* Cambridge, England: At the University Press, 1940. 93 pp.

For dielectrics (insulating materials in condensers) one may consult:

a. Frohlich, Herbert. *Theory of Dielectrics; Dielectric Constant and Dielectric Loss.* Oxford: At the Clarendon Press, 1949. 180 pp.

b. Whitehead, S. *Dielectric Phenomena.* London: Ernest Benn, Ltd., 1927-1932. 3 vols.

The coverage by volumes is: (1) Electrical discharges in gases; (2) Electrical discharges in liquids; and (3) Breakdown of solid dielectrics.

c. National Research Council. Conference on Electrical Insulation. *Digest of Literature on Dielectrics,* 1936 to date. Washington, D. C.: The Council, 1937 to date.

These annual surveys were originally called "Contributions of the Chemist to Insulation Research." (A single-volume reissue of vols. 1-10 (1936-1946) was published in 1949, without any combined index to authors or subjects.)

For piezoelectricity (electrical effects produced by pressure) we have:

a. Cady, Walter G. *Piezoelectricity; An Introduction to the Theory and Applications of Electromechanical Phenomena in Crystals.* New York: McGraw-Hill Book Company, 1946. 806 pp.

Historical development is sketched.

b. Mason, Warren P. *Piezoelectric Crystals and their Application to Ultrasonics.* New York: D. Van Nostrand Company, 1950. 508 pp.

Applied electricity.

Electrical engineering is beyond this *Guide's* scope, but it is

nevertheless based on physics, as Timbie and Bush agree:

> Fundamental physics which forms the basis for electrical engineering has made striking advances. Some of these, particularly in the field of atomistics, have been spectacular. A far better understanding is being secured of the difficult phenomena of the conduction of electricity through gases, liquids, and solids. The physics basis of electrical engineering is becoming more extended and better established.[26]

As first sources, one may consult the electrical engineering handbooks by Knowlton and Pender, *et al.*, as well as textbooks like the following:

a. Timbie, William H., and Bush, Vannevar. *Principles of Electrical Engineering.* (Fourth Edition.) New York: John Wiley and Sons, 1951. 626 pp.

b. Lawrence, Ralph R. *Principles of Alternating Current Machinery.* (Fourth Edition.) New York: McGraw-Hill Book Company, 1953. 623 pp.

c. Langsdorf, Alexander S. *Principles of Direct Current Machines.* (Fifth Edition.) New York: McGraw-Hill Book Company, 1940. 746 pp.

7— Electronics

General.

The present discussion centers upon electron flow rather than electrons as units of atomic structure, which are treated in Chapter X—Molecular. . . Physics. As previously noted, this field has its own periodical index, *Electronic Engineering Master Index,* which may be more convenient to use within its publication span than the general indexes. (Paralleling this since 1946 is the *Electronic Engineering Patent Index.*)

A well-rounded physical introduction is provided by:

Williams, Arthur O. *Electronics; Physical Principles and Applications.* New York: D. Van Nostrand Company, 1953. 306 pp.

Comprehensive treatments include the following:

a. Millman, Jacob, and Seely, Samuel. *Electronics.* (Second Edition.) New York: McGraw-Hill Book Company, 1951. 598 pp.

b. Dow, William G. *Fundamentals of Engineering Elec-*

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26. On page v of the third edition of their textbook next cited.

tronics. (Second Edition.) New York: John Wiley and Sons, 1952. 627 pp.

c. Andres, Paul G. *Survey of Modern Electronics.* New York: John Wiley and Sons, 1950. 522 pp.

The review series, *Advances in Electronics,* has been cited.

For experiments and measurements in electronics, see Chapter V.

Conduction in gases.

Ionization occurs when outer electrons are dislodged by collision or radiation and become current carriers. Classical works in this area are:

a. Townsend, Sir John S. E. *Electrons in Gases.* London: Hutchinson's Scientific and Technical Publications, 1947. 166 pp.

This carries forward work described in his earlier *Electricity in Gases* (1915).

b. Thomson, Sir Joseph J., and Thomson, Sir George P. *Conduction of Electricity through Gases.* (Third Edition.) Cambridge, England: At the University Press, 1928-1933. 2 vols.

The first edition, appearing in 1903, had named this field of experimentation.

A link between the foregoing classics and recent developments is provided by the following monograph by an outstanding specialist in the field:

Loeb, Leonard B. *Fundamental Processes of Electrical Discharge in Gases.* New York: John Wiley and Sons, 1939. 717 pp.

This well-organized critical survey is "based on the knowledge which modern atomic physics gives us, but which picks up the broken threads connecting the classical discharge theory of the textbooks and monographs with recent experimental developments."[27]

Other noteworthy textbooks are:

a. Maxfield, Frederick A., and Benedict, R. Ralph. *Theory*

27. *Op. cit.,* p. viii.

of Gaseous Conduction and Electronics. New York: McGraw-Hill Book Company, 1941. 483 pp.

b. Darrow, Karl K. *Electrical Phenomena in Gases.* Baltimore: Williams and Wilkins Company, 1932. 492 pp.

c. Engel, A. von, and Steenbeck, M. *Elektrische Gasentladungen; Ihre Physik und Technik.* Berlin: Springer, 1932-1934. 2 vols.

This is characterized as "admirable" by Loeb.

Gas discharge tables are found in:

Knoll, M., Ollendorff, F.; and Rompe, R. *Gasentladungstabellen; Tabellen, Formeln und Kurven zur Physik und Technik der Elektronen und Ionen.* Berlin: Springer, 1935. 171 pp.

Electron optics.

The behavior of electron beams in magnetic fields is described in:

a. Cosslett, Vernon E. *Introduction to Electron Optics.* Oxford: At the Clarendon Press, 1946. 272 pp.

b. Klemperer, Otto. *Electron Optics.* (Second Edition.) Cambridge, England: At the University Press, 1953. 471 pp.

c. Myers, L. M. *Electron Optics.* London: Chapman and Hall, Ltd., 1939. 618 pp.

This is a treatise for the graduate student interested in the field as a career.

For an important application to scientific research, electron microscopy, one may consult the following bibliographies and surveys:

a. Cosslett, Vernon E. *Bibliography of Electron Microscopy.* London: Longmans, Green and Company, 1951. 350 pp.

This includes 2,500 article references through 1948, arranged by author, with contents notes. It proceeds from the Institute of Physics centralized bibliographical project.

b. Marton, Claire, *et al. Bibliography of Electron Microscopy.* Washington, D. C.: Government Printing Office, 1950. 87 pp. (U. S. National Bureau of Standards Circular No. 502.)

c. Cosslett, Vernon E. *Practical Electron Microscopy.* New York: Academic Press, 1951. 299 pp.

d. Zworykin, V. K., *et al. Electron Optics and the Electron Microscope.* New York: John Wiley and Sons, 1945. 766 pp.

e. Wyckoff, Ralph W. G. *Electron Microscopy; Technique and Applications.* New York: Interscience Publishers, Inc., 1949. 248 pp.

f. Burton, E. F., and Kohl, W. H. *The Electron Microscope.* (Second Edition.) New York: Reinhold Publishing Corporation, 1946. 325 pp.

This well-illustrated presentation compares ordinary light microscopy with the new electron type.

Electronic tubes and circuits.

An excellent overall survey of theory and applications is furnished by:

Massachusetts Institute of Technology. *Applied Electronics; A First Course in Electronics, Electron Tubes, and Associated Circuits.* New York: John Wiley and Sons, 1943. 772 pp.

Some of the chapters are: Electron ballistics; Electron emission from metals; High vacuum electron tubes; and Polyphase rectifiers.

Tube theory of operation (rather than external circuits) is discussed from the physicist's standpoint in:

Koller, L. R. *The Physics of Electron Tubes.* (Second Edition.) New York: McGraw-Hill Book Company, 1937. 234 pp.

Other useful books on tubes and circuits follow:

a. Arguimbau, Lawrence B. *Vacuum Tube Circuits.* New York: John Wiley and Sons, 1948. 668 pp.

b. Eastman, Austin V. *Fundamentals of Vacuum Tubes.* (Third Edition.) New York: McGraw-Hill Book Company, 1949. 644 pp.

c. Reich, Herbert J. *Theory and Applications of Electron Tubes.* (Second Edition.) New York: McGraw-Hill Book Company, 1944. 716 pp.

d. Seely, Samuel. *Electron-tube Circuits.* New York: McGraw-Hill Book Company, 1950. 529 pp.

e. Spangenberg, Karl R. *Vacuum Tubes.* New York: McGraw-Hill Book Company, 1948. 860 pp.

See also the section Circuits in Chapter X—Electricity and Magnetism.

Electron emission.

Under suitable conditions, electrons will be emitted or dislodged by heat, light, or ion-bombardment.

Thermal emission, whereby charged particles leave heated filaments within radio and other types of vacuum tube, is well surveyed by:

a. Reimann, Arnold L. *Thermionic Emission.* New York: John Wiley and Sons, 1934. 324 pp.

b. Richardson, Owen W. *The Emission of Electricity from Hot Bodies.* (Second Edition.) London: Longmans, Green and Company, 1921. 320 pp.

Photoelectric emission is the liberation of electrons from light-sensitive surfaces, as described in:

a. Zworykin, V. K., and Ramberg, E. G. *Photoelectricity and Its Application.* New York: John Wiley and Sons, 1949. 494 pp.

b. Hughes, Arthur L., and DuBridge, Lee A. *Photoelectric Phenomena.* New York: McGraw-Hill Book Company, 1932. 531 pp.

Several bibliographies bearing on this subject are useful:

a. Doty, Marion F., compiler. *Selenium; A List of References, 1817-1925.* New York: The New York Public Library, 1927. 114 pp.

b. Bell Telephone Laboratories. *Bibliography of Articles on Photoelectricity, 1896-June 1930.* New York: Bell Telephone Laboratories, 1930. 145 pp.

c. Bell Telephone Laboratories. *Photoelectric Cells; Applications, 1913-1942.* New York: Bell Telephone Laboratories, 1942. 229 pp.

Cathode rays are electron streams emanating from a negative electrode subjected to ion bombardment in a gaseous discharge tube. An introductory description of such tubes is provided by:

Parr, Geoffrey. *The Cathode Ray Tube and Its Applications.* (Second Edition.) London: Chapman and Hall, Ltd., 1941. 180 pp.

Oscillographs chart electrical relationships by means of charged plates that deflect a cathode beam in perpendicular directions simultaneously. Two recent treatments are:

a. Rider, John F., and Uslan, Seymour D. *Encyclopedia on*

Cathode-ray Oscilloscopes and Their Uses. New York: John F. Rider Publisher, Inc., 1950. 992 pp.
This carefully compiled and comprehensive reference work covers theoretical considerations, equipment, circuits, wave-forms, and applications.

b. Wilson, William. *The Cathode Ray Oscillograph in Industry.* (Fourth Edition.) London: Chapman and Hall, Ltd., 1953. 273 pp.

X-rays.

These are high frequency waves emitted from substances hit by cathode rays. An old but still useful bibliography is:

Gocht, Hermann. *Die Rontgen-Literatur.* Stuttgart: Ferdinand Enke, 1911-1921. 4 vols.
This set covers physics and medical aspects, and has author, subject and patent approaches. The literature is surveyed through 1917.

There is also a comprehensive handbook:

Marx, Erich. *Handbuch der Radiologie.* Leipzig: Akademische Verlagsgesellschaft, 1920-1925. 6 vols. (A second edition of Vol. 6 has appeared in two parts, 1933-1934, under the title, *Quantenmechanik der Materie und Strahlung.*)

Theory and practice are presented in:

a. Compton, Arthur H., and Allison, Samuel K. *X-rays in Theory and Experiment.* (Second Edition.) New York: D. Van Nostrand Company, 1935. 828 pp.
Classical and quantum interpretations meet in this overall review.

b. Robertson, John K. *Radiology Physics.* (Second Edition.) New York: D. Van Nostrand Company, 1948. 323 pp.

c. Clark, George L. *Applied X-rays.* (Third Edition.) New York: McGraw-Hill Book Company, 1940. 674 pp.

d. St. John, Ancel, and Isenburger, Herbert R. *Industrial Radiology.* (Second Edition.) London: Chapman and Hall, Ltd., 1943. 298 pp.
A noteworthy feature is the comprehensive bibliography (pp. 233-289) of 1,314 references, continued by several supplements published separately later.

e. Sproull, Wayne T. *X-rays in Practice.* New York: McGraw-Hill Book Company, 1946. 615 pp.

Diffraction of X-rays and electrons may be effected not only by optical gratings, but also by crystals. This phenomenon has yielded a two-fold contribution to our knowledge of X-rays and crystal structure. Treatments include:

a. Pirenne, M. H. *The Diffraction of X-rays and Electrons by Free Molecules.* Cambridge, England: At the University Press, 1946. 160 pp.

b. Thomson, Sir George P., and Cochrane, W. *Theory and Practice of Electron Diffraction.* London: The Macmillan Company, 1939. 334 pp.

c. Randall, John T. *The Diffraction of X-rays and Electrons by Amorphous Solids, Liquids, and Gases.* London: Chapman and Hall, Ltd., 1934. 290 pp.

d. Bragg, Sir William H., and Bragg, Sir William Lawrence. *The Crystalline State.* London: G. Bell and Sons, 1948-1949. 2 vols., as follows:

Vol. 1: *A General Survey,* by Sir (William) Lawrence Bragg. 1949. 352 pp.

Vol. 2: *The Optical Principles of the Diffraction of X-rays,* by R. W. James. 1948. 623 pp.

The distinguished Braggs (father and son) jointly received the Nobel Prize in Physics in 1915 for their work in x-ray spectroscopy and crystal structure.

e. Zachariasen, William H. *Theory of X-ray Diffraction in Crystals.* New York: John Wiley and Sons, 1945. 255 pp.

f. Siegbahn, Manne. *Spektroskopie der Röntgenstrahlen.* (2. Auflage.) Berlin: Springer, 1931. 575 pp.

This is an excellent monograph on experimental X-ray spectroscopy and its significance for atomic physics. On pp. 488-560 literature is cited by years through 1931. (An English translation of the first German edition, 1923, had appeared in 1925.)

See also index under Crystallography and Spectroscopy.

Applied electronics.

As previously indicated, this *Guide* cannot deal extensively with applications, such as in radio, television, control, radar, etc. Volumes of the Massachusetts Institute of Technology *Radia-*

tion Laboratory Series[28] are valuable. Other useful sources include:

a. Terman, Frederick E. *Radio Engineering.* (Third Edition.) New York: McGraw-Hill Book Company, 1947. 969 pp.

b. Henney, Keith. *Radio Engineering Handbook.* (Fourth Edition.) New York: McGraw-Hill Book Company, 1950. 1197 pp.

c. Chute, George M. *Electronics in Industry.* New York: McGraw-Hill Book Company, 1946. 461 pp.

d. Fink, Donald G. *Television Engineering.* (Second Edition.) New York: McGraw-Hill Book Company, 1952. 721 pp.

Descriptions and circuits of radio and television receivers, public address systems, etc., may be found under model number in the indexes to John F. Rider's mammoth manual series.

8—Molecular, Atomic and Nuclear Physics

General.

Before consulting the standard textbooks, the beginner might well read more popular accounts, such as:

a. Hecht, Selig. *Explaining the Atom.* New York: Viking Press, 1947. 205 pp.

b. Gamow, G. *Mr. Tompkins Explores the Atom.* New York: The Macmillan Company, 1944. 97 pp.
Sound theory is whimsically presented in the guise of a bank clerk's dream adventures.

c. Thomson, Sir George P. *The Atom.* (Third Edition.) London: Oxford University Press, 1947. 196 pp.

Lucid treatments like the following may next be consulted:

a. Millikan, Robert A. *Electrons (+ and —), Protons, Photons, Neutrons, Mesotrons, and Cosmic Rays.* (Fourth Edition.) Chicago: University of Chicago Press, 1947. 642 pp.

b. Stranathan, J. D. *The "Particles" of Modern Physics.* Philadelphia: The Blakiston Company, 1942. 571 pp.

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28. Published by McGraw-Hill Book Company, 1947-1953, in 28 vols., the last of which is the index, prepared by Keith Henney.

The "particles" are: electrons; positive rays; photons; positrons; neutrons; mesotrons; X-rays; alpha, beta and gamma rays; cosmic rays.

c. Crowther, James A. *Ions, Electrons and Ionizing Radiations.* (Eighth Edition.) London: Edward Arnold and Company, 1949. 322 pp.

As indicated by number of editions published, this has been widely used.

(We are here concerned more with electrons in atomic structure rather than with their flow discussed in Chapter X—Electronics.)

From among many, the following general textbooks on atomic physics may now be chosen:

a. Born, Max. *Atomic Physics.* (Fifth Edition.) London: Blackie and Son, 1951. 437 pp.

b. Semat, Henry. *Introduction to Atomic Physics.* (Revised and Enlarged Edition.) New York: Rinehart and Company, 1946. 412 pp.

c. Hoag, J. Barton, and Korff, S. A. *Electron and Nuclear Physics.* (Third Edition.) New York: D. Van Nostrand Company, 1948. 522 pp.

d. Tolansky, Samuel. *Introduction to Atomic Physics.* (Third Edition.) New York: Longmans, Green and Company, 1949. 351 pp.

e. Dushman, Saul. *Fundamentals of Atomic Physics.* New York: McGraw-Hill Book Company, 1951. 294 pp.

A similar group bearing nuclear physics titles may be cited:

a. Blatt, John M., and Weisskopf, V. F. *Theoretical Nuclear Physics.* New York: John Wiley and Sons, 1952. 864 pp.

b. Pollard, Ernest C., and Davidson, W. L. *Applied Nuclear Physics.* (Second Edition.) New York: John Wiley and Sons, 1951. 352 pp.

c. Bitter, Francis. *Nuclear Physics.* Cambridge, Mass.: Addison-Wesley Press, 1950. 200 pp.

d. Halliday, David. *Introductory Nuclear Physics.* New York: John Wiley and Sons, 1950. 558 pp.

Collections of published accounts of major hypotheses and discoveries comprise an interesting and unusual compilation:

Foundations of Nuclear Physics; Facsimiles of Thirteen Fun-

damental Studies as They Were Originally Reported in the Scientific Journals. With a bibliography compiled by Robert T. Beyer. New York: Dover Publications, 1949. 272 pp.
The criteria of selection are frequency of subsequent citation, and amount of research stimulated. The bibliography is arranged in twelve sections, e.g., Radioactivity; Neutrons; Nuclear Fission.

A useful bibliography is available:

Tiomno, J., and Wheeler, John A. *Guide to Literature of Elementary Particle Physics, including Cosmic Rays.* 39 pp. (Reprinted from *American Scientist,* v. 37, nos. 2, 3; April, July 1949.)

See also the two review series, *Annual Review of Nuclear Science* and *Progress in Nuclear Physics.*

Among molecular phenomena of interest to physicists are capillarity, surface tension, adsorption, etc., treated in:

a. Adam, Neil K. *The Physics and Chemistry of Surfaces.* (Third Edition.) London: Oxford University Press, 1941. 436 pp.

b. Brunauer, Stephen. *The Adsorption of Gases and Vapors.* Princeton, N. J.: Princeton University Press, 1943. 511 pp.
This volume deals with physical adsorption.

c. Burdon, Roy S. *Surface Tension and the Spreading of Liquids.* (Second Edition.) Cambridge, England: At the University Press, 1949. 92 pp.

Atomic structure of metals and solids is covered by:

a. Seitz, Frederick. *The Physics of Metals.* New York: McGraw-Hill Book Company, 1943. 330 pp.
Some of the chapters are: Atomic arrangements in metals; Diffusion in metals; Development of the electron theory of metals; Magnetic properties of metals.

b. Seitz, Frederick. *The Modern Theory of Solids.* New York: McGraw-Hill Book Company, 1940. 698 pp.
This is an advanced treatise on "that phase of solid bodies that deals with electronic structure."

c. Kittel, Charles. *Introduction to Solid State Physics.* New York: John Wiley and Sons, 1953. 396 pp.

See also the index under Metals.

For crystal physics and structure, we have:

a. Wooster, William A. *A Text-book on Crystal Physics.* Cambridge, England: At the University Press, 1938. 295 pp.

b. Joffé, Abram F. *The Physics of Crystals.* New York: McGraw-Hill Book Company, 1928. 198 pp.

c. Wyckoff, Ralph W. G. *Crystal Structures.*[29] New York: Interscience Publishers, Inc., 1948- Vol. 1- (Looseleaf.)

d. *Internationale Tabellen zur Bestimmung von Kristallstrukturen.* (Revised Edition 1944 with an appendix of corrigenda.) Berlin: Gebrüder Borntraeger, 1935. 2 vols. (Lithoprinted by Edwards Brothers, 1944.)

X-ray crystallography has been discussed under the topic diffraction of X-rays.

Atomic energy.

This is briefly and lucidly surveyed in:

Darrow, Karl K. *Atomic Energy.* New York: John Wiley and Sons, 1948. 80 pp.

Two convenient reference works are:

a. Glasstone, Samuel. *Sourcebook on Atomic Energy.* New York: D. Van Nostrand Company, 1950. 546 pp.
Historical, theoretical and practical aspects are fully covered.

b. Gaynor, Frank. *Pocket Encyclopedia of Atomic Energy.* New York: Philosophical Library, 1950. 204 pp.

Additional help with unfamiliar terminology may be derived from the National Research Council glossary noted before under Physics Dictionaries in Chapter VIII.

There is also an extremely comprehensive bibliography:

United Nations. Atomic Energy Commission Group. *An International Bibliography on Atomic Energy.* New York: United Nations, 1949-1952.

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29. *See also* his *Structure of Crystals.* (Second Edition.) New York: The Chemical Catalog Company, 1931. 497 pp.; *Supplement for 1930-1934.* New York: Reinhold Publishing Corporation, 1935. 240 pp. The place of crystallography among the physical sciences is shown in his article, "Crystallography," in *Physics Today,* 5 (No. 10): 4-9, October 1952.

Vol. 1: *Political, Economic and Social Aspects.* 1949. 45 pp.
Supplement 1. 1950. 22 pp.
Vol. 2: *Scientific Aspects.* 1951. [880] pp.
Supplement 1. 1952. [325] pp.

Declassified material pertaining to atomic energy (more properly termed nuclear energy) may be found in volumes of the *National Nuclear Energy Series. Nuclear Science Abstracts* is the current indexing medium.

Underlying knowledge of the behavior of particles at high energies may be obtained from:

Rossi, Bruno B. *High-Energy Particles.* New York: Prentice-Hall, Inc., 1952. 569 pp.

High velocity may be imparted by the cyclotron and similar devices, described in:

a. Mann, W. B. *The Cyclotron.* (Third Edition.) New York: John Wiley and Sons, 1948. 92 pp.

b. Solomon, Arthur K. *Why Smash Atoms?* (Revised Edition.) Cambridge, Mass.: Harvard University Press, 1946. 204 pp.

Chain-reacting piles yield nuclear energy, but also isotopes and high-speed neutrons for research, as summarized in:

a. Goodman, Clark D., editor. *The Science and Engineering of Nuclear Power.* Cambridge, Mass.: Addison-Wesley Press, 1949-1952. 2 vols., as follows:

Vol. 1: *Introduction to Pile Theory.* (Second Edition.) 1952. 514 pp.

Vol. 2: *Applications of Nuclear Energy.* 1949. 317 pp.

b. Glasstone, Samuel, and Edlund, M. C. *The Elements of Nuclear Reactor Theory.* New York: D. Van Nostrand Company, 1952. 416 pp.

c. Soodak, Harry, and Campbell, Edward C. *Elementary Pile Theory.* New York: John Wiley and Sons, 1950. 73 pp.

d. Hughes, Donald J. *Pile Neutron Research.* Cambridge, Mass.: Addison-Wesley Press, 1953. 386 pp.

See also the experimental-nucleonics books listed in Chapter V; and the comprehensive review (by H. A. Bethe, R. F. Bacher and M. S. Livingston) of early nuclear physics developments, appearing in *Reviews of Modern Physics* for April 1936, April

1937, and July 1937, these issues being reprinted because of demand.

Radiation[30] and other hazards are considered in:

a. National Research Council. Committee on Nuclear Science. Subcommittee on Radiobiology. *Symposium on Radiobiology; The Basic Aspects of Radiation Effects on Living Systems,* edited by James J. Nickson. New York: John Wiley and Sons, 1952. 465 pp.

b. Shamos, Morris H., and Roth, Sidney C. *Industrial and Safety Problems of Nuclear Technology.* New York: Harper and Brothers, 1950. 368 pp.

This is a compilation of papers read at a New York University symposium.

c. Lapp, Ralph E., and Andrews, H. L. *Nuclear Radiation Physics.* New York: Prentice-Hall, Inc., 1948. 487 pp.

d. Gray, Dwight E., and Martens, J. H. *Radiation Monitoring in Atomic Defense.* New York: D. Van Nostrand Company, 1951. 122 pp.

See also index under Radiation, and the following section.

Radioactivity.

Uranium and other heavy elements are constantly emitting alpha, beta and gamma rays as they slowly disintegrate. This process is called natural radioactivity, as distinct from artificial radioactivity in which unstable nuclei produced by neutron bombardment behave similarly. Pioneer work by the Curies is described in:

Curie, Marie Sklodowska. *Radioactivité.* Paris: Hermann et Cie., 1935. 563 pp.

Comprehensive surveys distinguished by clarity of presentation are:

a. Rutherford, Sir Ernest; Chadwick, James; and Ellis, C. D. *Radiations from Radioactive Substances.* Reprinted with corrections. Cambridge, England: At the University Press, 1951. 588 pp.

b. Hevesy, George, and Paneth, F. A. *A Manual of Radio-*

30. An interesting résumé of common exposures is furnished by: F. P. Cowan, "Everyday Radiation." *Physics Today,* 5 (No. 10): 10-16, October 1952.

activity. (Second Edition.) London: Oxford University Press, 1938. 306 pp.

c. Moon, Philip B. *Artificial Radioactivity.* Cambridge, England: At the University Press, 1949. 102 pp.

See also index under Radioactivity.

Isotopes.

Most elements are comprised of isotopes, which have different atomic weights but the same atomic number in the periodic table. (Atomic numbers represent number of protons in the nucleus.) Isotope mass measurements are outlined in:

a. Aston, Francis W. *Mass Spectra and Isotopes.* (Second Edition.) New York: Longmans, Green and Company, 1942. 276 pp.

b. *Mass Spectroscopy in Physics Research.* Washington, D. C.: Government Printing Office, 1953. 273 pp. (U. S. National Bureau of Standards Circular No. 522.)

"A complete list of all the radioactive and stable isotopes of the elements, together with a number of their salient features, as recorded in the literature or by private communication by approximately December, 1952" is furnished by:

Hollander, J. M.; Perlman, I.; and Seaborg, G. T. "Table of Isotopes." *Reviews of Modern Physics,* 25: 469-651, April 1953.

A convenient chart (small and wall size) is described by its publisher, Addison-Wesley Press, as follows:

> Segrè Isotope Chart: This chart contains a fairly complete summary of some of the more important properties of nuclei, both stable and radioactive. Atomic number is plotted against a vertical scale of A-Z (the number of neutrons in the nucleus). In the square for each isotope the properties of the particular isotope are listed as far as available information allows.

Other charts[31] and tables useful in nuclear physics are:

a. Sullivan, William H. *Trilinear Chart of Nuclear Species.* New York: John Wiley and Sons, 1949. (Six panels within cover; gummed for assembly.)

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31. For an interesting discussion of isotope charts, see B. T. Feld's review in *Physics Today,* 3 (No. 5): 38-39, May 1950.

b. Mattauch, Josef. *Nuclear Physics Tables.* New York: Interscience Publishers, Inc., 1946. 173 pp.
(The tables are combined with *An Introduction to Nuclear Physics* by S. Fluegge.)

c. *Nuclear Data.* Washington, D. C.: Government Printing Office, 1950. 309 pp. (U. S. National Bureau of Standards Circular No. 499.) Also *Supplements* 1-3, 1950-1951.[32] Other collections of nuclear data are listed on pp. 275-276 of the main volume.

Cosmic rays.

These are charged particles radiated towards earth from outer space. Three popular accounts are:

a. Auger, Pierre. *What are Cosmic Rays?* (Revised and enlarged American Edition.) Chicago: University of Chicago Press, 1945. 128 pp.

b. Millikan, Robert A. *Cosmic Rays.* New York: The Macmillan Company, 1939. 134 pp.

c. Leprince-Ringuet, Louis. *Cosmic Rays.* New York: Prentice-Hall, Inc., 1950. 290 pp.

A more advanced treatment is provided by:

Jánossy, Lewis. *Cosmic Rays.* Oxford: at the Clarendon Press, 1948. 424 pp.

Superbly reproduced pictures of cloud chamber radiation are found in:

Rochester, G. D., and Wilson, J. G.[33] *Cloud Chamber Photographs of the Cosmic Radiation.* New York: Academic Press, 1952. 128 pp.

For the review series, *Progress in Cosmic Ray Physics,* see Chapter II.

Applied atomics.

Military, industrial and medical potentialities of atomic energy are great. The first comprehensive report on the atomic

32. New nuclear data gathered since July 1951 appeared instead in *Nuclear Science Abstracts,* as previously noted.
33. See also J. G. Wilson, *The Principles of Cloud-Chamber Technique.* Cambridge, England: At the University Press, 1951. 131 pp.

bomb was issued as a U. S. government publication, and also by the Princeton University press:

Smyth, Henry De Wolf. *Atomic Energy for Military Purposes.* Princeton, N. J.: Princeton University Press, 1945. 264 pp.

British activity is related in:

Harwell; the British Atomic Energy Research Establishment, 1946-1951. New York: Philosophical Library, 1952. 128 pp.

Various applications are reviewed in:

a. Smith, Edward S. C., *et al. Applied Atomic Power.* New York: Prentice-Hall, Inc., 1946. 227 pp.

b. Rothmann, S. C., editor. *Constructive Uses of Atomic Energy.* New York: Harper and Brothers, 1949. 258 pp. Some of the chapters in this compilation are: Atomic energy in industry and the physical sciences; Industrial applications of radioactivity; Atomic power for industry; Medical uses of atomic energy. Chronology, glossary, and bibliography are appended.

c. Gamow, George. *Atomic Energy in Cosmic and Human Life.* New York: The Macmillan Company, 1946. 161 pp. Its three sections are: Modern alchemy; How the stars use atomic energy; How can man use atomic energy?

d. Newman, James R., and Miller, Byron S. *The Control of Atomic Energy; A Study of its Social, Economic and Political Implications.* New York: McGraw-Hill Book Company, 1948. 434 pp.

9—Related Fields

Astrophysics.

This is the region in which astronomy and physics overlap. An introductory treatment and an advanced current review follow:

a. Dingle, Herbert. *Modern Astrophysics.* (Second Edition.) New York: The Macmillan Company, 1927. 420 pp. The four parts are: Spectroscopy; Characteristics of the stars; Varieties of cosmic bodies; The universe.

b. Hynek, J. A., editor. *Astrophysics: A Topical Sympos-*

ium. New York: McGraw-Hill Book Company, 1951. 703 pp.

The field boasts a monumental reference set:

Handbuch der Astrophysik, herausgegeben von G. Eberhard, *et al.* Berlin: Springer, 1928-1936. 7 vols. in 10.

Biophysics.

In a useful overall summary,[34] Loofbourow characterizes this field as follows:

> ...Biophysics may be said to include all applications of physics to the study or explanation of biological systems. Biophysics so defined may conveniently be divided into three aspects, as follows: (i) the physics of living organisms, (ii) the biological effects of physical agents, and (iii) the use of physical methods and measurements in the study of biological structures and functions.

More extensive treatments include:

a. Stuhlman, Otto. *An Introduction to Biophysics.* New York: John Wiley and Sons, 1943. 375 pp.

To show the wide range of topics, the contents are: Biophysically active X-rays; Applied radioactivity; Biophysical characteristics of the eye; Emission and absorption of biophysically active light; Structure and properties of surfaces and membranes; Biophysical problem of nerve conduction; Auditory biophysics; Compound microscope; Electron microscope.

b. Glasser, Otto. *Medical Physics.* Chicago: The Year Book Publishers, 1944-1950. 2 vols.

The second volume supplements the first. The set has an enormous quantity of material of interest to general physics, despite the "medical" title.

For two review series, *Progress in Biophysics and Biophysical Chemistry* and *Advances in Biological and Medical Physics,* see Chapter II.

"Physics in Relation to Medicine"[35] was the subject of an

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34. J. R. Loofbourow, "Biophysics." *American Journal of Physics,* 15: 21-30, January-February 1947.

35. See also: C. T. Van Meter, "Some Applications of Physics in Pharmacy." *American Journal of Physics,* 8: 290-293, October 1940; and E. W. Skinner, "College Physics as a Requirement for Entrance to Dental School." *American Physics Teacher,* 6: 253-255, October 1938.

American Physical Society report in *American Physics Teacher*, 2: 48-52; 101-107, May and September, 1934.

Chemical physics.

A good introduction to this dual field is:

Slater, J. C. *Introduction to Chemical Physics.* New York: McGraw-Hill Book Company, 1939. 521 pp.

The author explains the union of the two branches as follows (p. v):

> It is probably unfortunate that physics and chemistry ever were separated. Chemistry is the science of atoms and of the way they combine. Physics deals with the interatomic forces and with the large-scale properties of matter resulting from those forces. So long as chemistry was largely empirical and nonmathematical, and physics had not learned to treat small-scale atomic forces, the two sciences seemed widely separated. But with statistical mechanics and the kinetic theory on the one hand and physical chemistry on the other, the two sciences began to come together. Now that statistical mechanics has led to quantum theory and wave mechanics, with its explanations of atomic interactions, there is really nothing separating them any more. . . . For want of a better name, since Physical Chemistry is already preempted, we may call this common field Chemical Physics.

Geophysics.

Various phases of geophysics are spanned by the series:

Physics of the Earth. Washington, D. C.: National Research Council, 1931-1942. 9 vols.

Individual volumes are: I, Volcanology; II, Figure of the earth; III, Meteorology; IV, Age of the earth; V, Oceanography; VI, Seismology; VII, Internal constitution of the earth; VIII, Terrestrial magnetism and electricity; IX, Hydrology.

The prefaces state:

> It is generally agreed that more attention should be given to research in the middle ground between the sciences. Geophysics—the study by physical methods of the planet on which we live—is a conspicuous example of such middle-ground science, as it slides off imperceptibly in one direction or another into the fields of physics, astronomy, and geology, to say nothing of biology, with which the subject of oceanography is closely connected. Some branches of geophysics, such as meteorology, terrestrial magnetism, geodesy, and oceanography, have long been studied more or less independently, but it has become in-

creasingly clear that these subjects and many others are all parts of geophysics.

Atmospheric effects are described in:

a. Humphreys, William J. *Physics of the Air.* (Third Edition.) New York: McGraw-Hill Book Company, 1940. 676 pp.

Its five parts are: Mechanics and thermodynamics of the atmosphere; Atmospheric electricity and auroras; Meteorological acoustics; Atmospheric optics; Factors of climatic control.

b. American Meteorological Society. *Compendium of Meteorology,* edited by Thomas F. Malone. Boston: The Society, 1951. 1334 pp.

This is both comprehensive and authoritative.

For the review series, *Advances in Geophysics,* and mention of *Meteorological Abstracts,* see Chapter II.

General Summary

Every special subject guide is expected to point out important landmarks and indicate how to proceed beyond. Two methods of compilation are possible: (1) all book citations not too obviously disqualified might be copied from library card catalogs so as to form an imposing bibliographical array termed "comprehensive"; or (2) books could be carefully examined, compared, selected and organized for the purpose of guiding rather than impressing the user. The latter alternative has been adopted.

Accordingly, the materials included constitute points of departure rather than the whole printed record. This guide attempts to cover most important aspects and topics of physics literature by citing a few representative sources in each category. Library tools and techniques have been described. Attention has constantly been called to special types of publication which fulfill a unique purpose, such as Magie's *Source Book,* Higgins' biographical lists, Sutton's *Demonstration Experiments,* Smith's *Careers in Physics,* etc. These useful and interesting compilations are too frequently overlooked.

As physics literature becomes increasingly voluminous, the importance of knowing how to utilize its hidden resources efficiently grows apace. Library guides in special subject fields have been characterized as signposts. If the present guide beckons users toward the desired ends of their literature searches, it will have achieved its purpose.

General Bibliography

The following references have proved helpful in the preparation of this *Guide,* and may be used in conjunction with it:

Alexander, C., and Burke, A. J. *How to Locate Educational Information and Data.* (Third Edition.) New York: Bureau of Publications, Teachers College, Columbia University, 1950. 441 pp.

American Chemical Society. *Searching the Chemical Literature.* Washington, D. C.: The Society, 1951. 184 pp.

Crane, E. J., and Patterson, A. M. *A Guide to the Literature of Chemistry.* New York: John Wiley and Sons, 1927. 438 pp.

Dyson, G. M. *A Short Guide to Chemical Literature.* London: Longmans, Green and Company, 1951. 144 pp.

Holmstrom, J. E. *Records and Research in Engineering and Industrial Science.* (Second Edition.) London: Chapman and Hall, Ltd., 1947. 366 pp.

Jackson, L., editor. *Technical Libraries; Their Organization and Management.* New York: Special Libraries Association, 1951. 202 pp.

Jones, E. L. "Searching the Literature of Science." *Journal of Scientific Instruments,* 17: 253-257, November 1940.

Mellon, M. G. *Chemical Publications; Their Nature and Use.* (Second Edition.) New York: McGraw-Hill Book Company, 1940. 284 pp.

Miller, G. A. *Historical Introduction to Mathematical Literature.* New York: The Macmillan Company, 1916. 302 pp.

Parke, N. G. *Guide to the Literature of Mathematics and Physics, Including Related Works on Engineering Science.* New York: McGraw-Hill Book Company, 1947. 205 pp.

Roberts, A. D. *Guide to Technical Literature.* London: Grafton and Company, 1939. 279 pp.

Roberts, A. D. *Introduction to Reference Books.* (Second Edi-

tion.) London: The Library Association, 1951. (Reprinted 1952.) 214 pp.

Soule, B. A. *Library Guide for the Chemist.* New York: McGraw-Hill Book Company, 1938. 302 pp.

Spratt, H. P. *Libraries for Scientific Research in Europe and America.* London: Grafton and Company, 1936. 227 pp.

Wheeler, J. A., and Shields, M. C. "Condensed Library Guide for the Physicist." *Review of Scientific Instruments,* 13: 197-198, April 1942.

Whitford, R. H., and O'Farrell, J. B. "Use of a Technical Library." *Mechanical Engineering,* 70: 987-993, December 1948.

Winchell, C. M. *Guide to Reference Books,* based on the... sixth edition by I. G. Mudge. (Seventh Edition.) Chicago: American Library Association, 1951. 645 pp. *1st Supplement:* 1950-1952, by C. M. Winchell and Olive Johnson. A. L. A., 1954. 144 pp.

Woodring, M. N.; Oakes, M. E.; and Brown, H. E. *Enriched Teaching of Science in the High School.* (Second Edition.) New York: Bureau of Publications, Teachers College, Columbia University, 1941. 402 pp.

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